# How to engage students for **STEM?**

## Analysing the ingredients for a motivational cocktail in the learning environment

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# How to engage students for STEM? Analysing the ingredients for a motivational cocktail in the learning environment.

## Hoe studenten engageren voor STEM? Een analyse van de ingrediënten voor een motivationele cocktail in de leeromgeving.

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Annemie Struyf

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*"I never failed once. It just happened to be a 2000-step process."*

– T. Edison

Een doctoraat; het was een proces van `trial and error`. Gelukkig kon ik tijdens dit proces een beroep doen op collega`s, familie en vrienden. Hierdoor werd het niet alleen een leerrijk, maar ook een leuk traject dat ik tot op het einde kon volhouden en dat geleid heeft tot het werk dat er nu ligt.

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# CHAPTER 1

# Introduction

## Introduction

### *The Importance of Science, Technology, Engineering, and Mathematics (STEM) and the current challenges*

The processes of globalisation and technology are increasingly shaping today's society. Technology is rapidly altering the way we communicate and work, intertwining communities and companies in increasingly sophisticated ways (World Economic Forum [WEF], 2017). This reality creates new challenges for policy makers, scholars and society as a whole. One of these challenges is to prepare all citizens sufficiently for the demands of modern life and the requirements of the new labour market. Another challenge is to provide society with a greater number of specialised professionals in the fields of Science, Technology, Engineering and Mathematics (STEM). Among other things, these professionals are required to address complex societal challenges regarding energy, transportation, clean water, climate change and healthcare (Bøe, Henriksen, Lyons, & Schreiner, 2011; Nadelson & Seifert, 2017; National Academic Press [NAP], 2018).

Education systems especially have a crucial role to play in engaging and preparing (young) people in STEM. Current international achievement studies such as TIMSS (Trends in International Mathematics and Science Study) indicate some positive trends regarding students' achievement and attitudes towards science and mathematics (Knipprath et al., 2018). For example, between 1995 and 2015 there were more countries where students' achievement in science and mathematics increased than countries where their performance level decreased. Moreover, the number of students 'liking science' has increased in half of the participating countries in TIMSS (Knipprath et al., 2018; Mullis, Martin, & Loveless, 2016; Mullis, Martin, Foy, & Hooper, 2018).

Despite some positive trends, many challenges exist to engage students in STEM education and careers. Firstly, students' engagement in STEM appears to decrease with age. The number of students who like science and mathematics drops between the $4^{th}$ and $8^{th}$ grade (Mullis, Martin, & Loveless, 2016; Knipprath et al., 2018). Additionally, encouraging students to choose a STEM subject in tertiary education is a major challenge, as students' disengagement from STEM is most apparent during the transition from secondary to higher education in many countries. In highly developed countries particularly, there is a shortage of university students taking hard science, compared to soft science. The latter includes biology and health issues, while hard science typically covers technology, engineering, mathematics, physics, and to some extent, chemistry (Bøe et al., 2011). Secondly, women and minority groups are underrepresented in STEM education and careers and women are particularly underrepresented in the field of hard science. Engaging women and minority groups in STEM is not only necessary to increase the number of STEM professionals; it is also an educational priority to provide all citizens with sufficient STEM literacy (Bøe et al., 2011) which refers to the understanding of fundamental concepts of each STEM discipline and an awareness of their role in society (Honey, Pearson, & Schweingruber, 2014; Koul, Fraser, Maynard, & Tade, 2017). STEM literacy empowers people as it helps them to shape their everyday life and actively participate in society in general.

However, as the World Economic Forum (2017) states, simply engaging more students in STEM education and careers is not sufficient within the current framework of education. Presently, the instruction of STEM subjects often focuses on theory over application and experiential learning which reinforces a disconnect between the different STEM disciplines and the 'real world' and prepares students insufficiently for the skills they will need in the modern labour market (WEF, 2017). As 21st century skills such as creativity, problem-solving, critical thinking and collaboration are crucial within the fields of STEM (Binkley et al., 2012; Salonen, Hartikainen-Ahia, Hense, Scheersoi, & Keinonen; 2017), a shift towards other educational approaches in STEM is necessary (Nadelson & Seifert, 2017; WEF, 2017).

To respond to these issues, a research and development project called STEM@School has been established in Flanders to investigate how to optimally engage and prepare students in STEM. Over the timeframe of 2014-2018, STEM@School collaborated with approximately 20 schools to develop, trial and implement a novel approach, called integrated STEM (iSTEM) education. Within the project, four Ph.D. researchers focused on the development of iSTEM learning materials and two Ph.D. researchers took an evaluative research perspective. The current dissertation is framed within the evaluative section of the project and specifically aims to deepen our understanding of student engagement in STEM and contextual factors within diverse STEM learning environments that are crucial to engaging students in STEM. In the introduction of this dissertation, we discuss how the challenges relating to STEM occur in the context of Flanders and how the STEM@School project aims to respond to them. Furthermore, we present the theoretical framework of this dissertation and provide an overview of the different chapters.

## The case of Flanders

In Flanders (the Dutch-speaking community of Belgium), secondary education students often choose to study a STEM-oriented subject. 36% of students in the 8th grade choose a STEM-oriented subject and 45% in the 10th grade. At secondary education level, 45% of students graduate from a study programme with a strong focus on science, mathematics or technology (STEM monitor, 2018). The science and mathematics study programme is the most popular study choice in general secondary education and many girls choose it (Van den Berghe & De Martelaere, 2012; Knipprath et al., 2018). Just as in many other countries, the main problem occurs during the transition from secondary to tertiary education (Bøe et al., 2011), as many Flemish students do not choose a STEM subject when they enter higher education. Currently, only 44% of the students who obtain a secondary education STEM diploma take a STEM-oriented subject in higher education (STEM monitor, 2018).

On the initiative of the Flemish government, many Flemish schools started to implement small-scale STEM projects to arouse pupils' interest in STEM, during the last 5 to 10 years. However, there were no well-defined guidelines for the development of learning material and the instructional approach for these projects. Moreover, these projects mainly targeted elementary school students and students in the 7th and 8th grades and focused on technology, which undervalued the need to integrate technology with other STEM disciplines (Knipprath et al. 2018). To respond to these needs, the STEM@School research and development project, began to develop research-based learning material to create large and sustainable STEM projects in secondary education from the 9th grade upwards (Knipprath et al., 2018).

## *How STEM@School aims to prepare and engage students in STEM*

STEM@School is a collaborative project between the University of Leuven, University of Antwerp, and the educational umbrella organisations Catholic Education Flanders and GO! The overall aim of the project is to increase students' achievement, motivation and engagement in STEM, by providing and implementing integrated STEM education in secondary education.

*The key principles and theoretical foundation of integrated STEM education*

The main principle of integrated STEM (iSTEM) education is to combine and integrate the four disciplines of Science, Technology, Engineering, and Mathematics (STEM) in one class, unit or lesson (Moore & Smith, 2014), typically through project or problem-based learning (e.g. inquiry or design challenges) (Nadelson & Seifert, 2017). The idea behind iSTEM education originates from the fact that most of the problems occurring in industry and society are complex and trans disciplinary. Consequently, solving this type of problems requires knowledge and practices from various STEM disciplines and solutions can vary widely (Nadelson & Seifert, 2017; Wang, Moore, Roehrig, & Park, 2011).

Currently, in contrast with reality, STEM is often taught as separate disciplines (e.g. traditional physics and chemistry). This involves the application of knowledge and practice in one single STEM discipline and the solutions are often restricted to one single answer. This contrast between the 'segregated STEM' taught in schools and the integrated nature of STEM in society negative impacts on students' preparedness for the STEM labour market (Nadelson & Seifert, 2017). Therefore, the current international focus includes a push towards a greater mixture of segregated foundational STEM knowledge with integrated project-based STEM (Koul et al., 2017, Nadelson & Seifert, 2017).

Although many researchers and educational practitioners advocate iSTEM education, there is a lack of consensus about its instructional practices and theoretical foundations (Thibaut et al., 2018a). In recent years many researchers have provided detailed information about the iSTEM learning units they designed but have not described how these units should be taught and learned (e.g. Gentile et al., 2012; Barret, Moran, & Woods, 2014). On the other hand, other researchers have extensively reported their ideas about the instructional practices for iSTEM education, but they have not provided a theoretical foundation for them (e.g. Sanders, 2009; Moore & Smith, 2014).

Consequently, STEM@School has provided a theoretical framework for instructional practices in iSTEM education, based on a review of existing literature (Thibaut et. al, 2018a). Five key principles that can guide the design for iSTEM learning modules in secondary education are included (Figure 1).

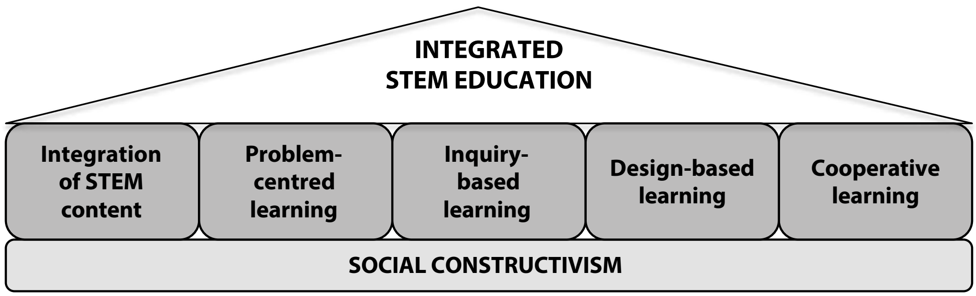



**Figure 1.** Theoretical framework for integrated STEM education (Thibaut et al., 2018a)

All the principles depart from a social constructivist view of learning, which entails the idea that learning is an active process of individuals constructing meaning for themselves. Thus, significant understanding is not just 'received'. The meaning that each individual constructs depends on their prior conceptions. Moreover, the social aspect of social constructivism dictates that meanings are socially constructed; understanding is enriched by the engagement of ideas in concert with others (Anderson, 2007). The 5 distinctive but related key principles for iSTEM are described as follows:

- *The integration of STEM content*: entails purposefully making connections between the different STEM disciplines. Making the integration explicit is important, because students do not spontaneously integrate concepts on their own. Moreover, students' knowledge within the individual disciplines needs to be supported, in order that they have sufficient understanding to connect ideas across disciplines (Pearson, 2017; Thibaut et al., 2018a).

- *Problem-centred learning*: indicates the use of authentic real-world problems to increase the relevance of the learning content. Importantly, the real-world problem needs to be introduced at the start of instruction or learning unit. This allows students to activate mental models early in the learning sequence and connect new information and experiences to their prior knowledge in a meaningful way (Ashgar, Ellington, Rice, Johnson, & Prime, 2012).

- *Inquiry-based learning*: refers, in this context, to engaging students in questioning, experiential learning and hands-on activities that allows them to actively discover new concepts and develop new understanding. Students need to question their current knowledge about a certain topic and discover what additional knowledge is required to move forward (Thibaut et al., 2018a). An appropriate amount of guidance is necessary to help students to discover any shortcomings in their reasoning or research design, ultimately helping them to arrive at a solution and bringing them into contact with the to-be learned content (Buck, Bretz, & Towns, 2008; Thibaut et al., 2018a).

- *Design-based learning*: refers to learning environments that engage students in technological or engineering design. Effective design challenges should be open-ended, authentic, hands-on, and multidisciplinary (Shahali, Halim, Rasul, Osman, & Zulkifeli, 2017). In addition, the engineering design process should entail different iterative phases, such as defining engineering problems, designing engineering solutions, and implementing, testing, evaluating and optimising a solution (Thibaut et al., 2018a)

- *Cooperative learning*: relates to the promotion of teamwork and collaboration with others through the use of, for example, small learning groups. The teacher moves from one student group to the other, observes and intervenes when necessary. Moreover, training in small-group social skills is offered and the teacher stimulates the students to assess the functioning of the group to improve their performance (Matthews, 1995; Thibaut et al., 2018a).

An example of one of the STEM@school learning modules that was designed around these key principles, is described and shown in Figure 2[1]

**Learning module – The rehabilitation device**

An example from one of the learning modules from STEM@School, developed for 9th grade students, consists of the design of a rehabilitation device. The challenge is centred around a boy Martijn who had a car accident and needs to regain the strength of the muscles in his arm *(problem-centred learning)*. In addition to some lectures for the whole class group, students are supposed to work in teams of 3-4 to solve the problem *(cooperative learning)*. Guided by the teacher, they have to look up information and conduct experiments in order to acquire the right knowledge *(inquiry-based learning).* As the problem is a real-world challenge, knowledge from different STEM disciplines is required. The mathematics content includes 'vectors'. The physics content consists of measuring 'forces'. The necessary technology knowledge concerns the use of a pulley and gear wheels *(integration of STEM content).* Combining this acquired knowledge is necessary to design an appropriate rehabilitation device *(design-based learning).*

**Figure 2:** An Example of 9th grade students' design of a rehabilitation device

1 Other examples of learning modules and specific learning materials can be found on the website: http://www.stematschool.be/en/our-learning-modules.

*Is iSTEM education a promising approach for increasing students' preparation and engagement in STEM?*

Considering the key principles of iSTEM education, the STEM@School project aims to respond to the current challenges regarding students' preparation and engagement in STEM. First, iSTEM aims to prepare students better for the modern labour market by promoting the development of important 21$^{st}$ century skills, such as problem solving, critical thinking, creative and innovative thinking, and collaboration and teamwork skills (Binkley et al., 2012; Thibaut et al., 2018a).

Second, the integration of STEM content to solve real-world problems encourages students to understand the relevance of STEM, which is expected to increase their levels of interest and engagement in STEM (Nadelson & Seifert, 2017; Knipprath et al., 2018). Students who have a high level of interest in societally relevant topics, will possibly be more triggered if the STEM learning content is linked to a challenge that concerns, for example, health care (e.g. the module concerning the rehabilitation device) or climate change. Besides increasing the relevance of the learning content, the didactics of the other 4 key principles aim to increase students' engagement, as they require a student-centred approach. This implies that students take an active role in their learning instead of being passive receivers of information, and that teachers should become a coach and facilitator instead of a dispenser of knowledge (Anderson, 2007; Brush & Saye, 2000).

To summarise, iSTEM education seems to be a promising approach for preparing and engaging students in STEM. However, as there is little research into students' engagement with integrated STEM learning environments, we aim to verify which factors are significant for students' engagement in this learning environment.

## Conceptual framework

The overall aim of this dissertation is to gain an insight into which factors are important for supporting and facilitating secondary school students' engagement in iSTEM learning environments, and also in conventional STEM learning environments. In this section, we discuss the theoretical and analytical framework of the dissertation.

### *Defining student engagement*

Engagement refers to 'the behavioural intensity and emotional quality of a person's active involvement during a task' (Reeve, Jang, Carrell, Jeon, & Barch, 2004, p. 147). Students who are behaviourally engaged, work hard, take initiative and persist during challenging learning activities. Moreover, they are emotionally engaged during these learning activities if they show interest, enthusiasm and zest for learning. In contrast, disengagement or disaffection is evident in students who are bored, passive and give up easily (Skinner, Furrer, Marchand, & Kindermann, 2008; Skinner et al., 2017). Several researchers consider engagement to be the externalisation of motivation (Stroet, Opdenakker, & Minnaert, 2013; Ryan, 2017). Ryan and Deci (2000) describe motivation as a person's activation and intention. In other words, it concerns the reasons for a person's behaviour (Ryan & Deci, 2000). The concept of engagement is of particular interest due to its role in promoting persistence in STEM education and a STEM career choice (Sinatra, Heddy, & Lombardi, 2015), as it predicts students' success and long-term engagement (Reeve, 2012; Skinner et al., 2017).

Engagement can be approached and measured differently based on the 'grain size' of the context, which can range from the individual level, such as a person's individual engagement during a task, to the macro level, which is the engagement of a group of learners in a class, course, school or community (Sinatra, Heddy, & Lombardi, 2015). In this dissertation, we focus on and measure both students' individual engagement and students' collective classroom engagement. It is important to measure both the individual and collective perspectives of students' engagement in STEM learning environments. Measuring students' collective engagement in relation to the learning environment provides insight into how to create a motivational atmosphere that engages a group of learners. In contrast, investigating students' individual engagement deepens our understanding about the interplay or relation between the individual, his or her personal characteristics (e.g. educational achievement, personal values, ethnic-cultural background) and aspects within the STEM learning environment.

### *A Self-Determination Theory approach to studying students' engagement in STEM*

In this dissertation, we use the Self-Determination Theory (SDT) perspective to identify and understand the elements essential to motivate and engage pupils in the STEM learning environment. SDT differs from social cognitive and expectancy-value models, which are extensively centred on students' self-efficacy as the crucial motivational asset and the role of socialisation processes for motivation, such as values and goals espoused by parents or the study strategies students have been taught (see Eccles & Wigfield, 2002 for a review of models of motivation; Skinner et al., 2017). Thus, these socialisation experiences - which may differ for students' from disadvantaged backgrounds - are considered as sources of students' current motivation, typically operationalised as values, expectancies (or efficacy) and goal orientations, which in turn contributes to their efforts and persistence (Skinner et al., 2017).

In contrast, SDT highlights the vital role of intrinsic motivation, common to all students regardless of social background or prior experience (Skinner et al., 2017). When students are intrinsically motivated, they engage in an activity because they are interested in and enjoy it, while students who are extrinsically motivated engage in activities due to external factors such as pressure or rewards (Ryan & Deci, 2000; Eccles & Wigfield, 2002). SDT literature posits and continues to find that higher motivation, engagement, performance and well-being can be reached through the fulfilment of three fundamental psychological needs, intrinsic to all humans (Deci & Ryan, 2002; Reeve, 2012). These needs are: (1) autonomy – the need to perceive one's true self as the source of motivation and action (2) relatedness – the need to feel connected and have a 'sense of belonging' towards others, and, (3) competence – the need to feel effective and capable (Deci & Ryan, 2002, Skinner et al., 2017).

Importantly, the social context can support or thwart an individuals' basic psychological needs. Skinner et al. (2017) built further on SDT and developed a theoretical framework, which shed light on the contextual factors that are significant for students' engagement in STEM learning environments. The theoretical framework provides a good overview of the theoretical background and central concepts within this dissertation. Therefore, we positioned the studies discussed in this dissertation within this framework (Figure 3).

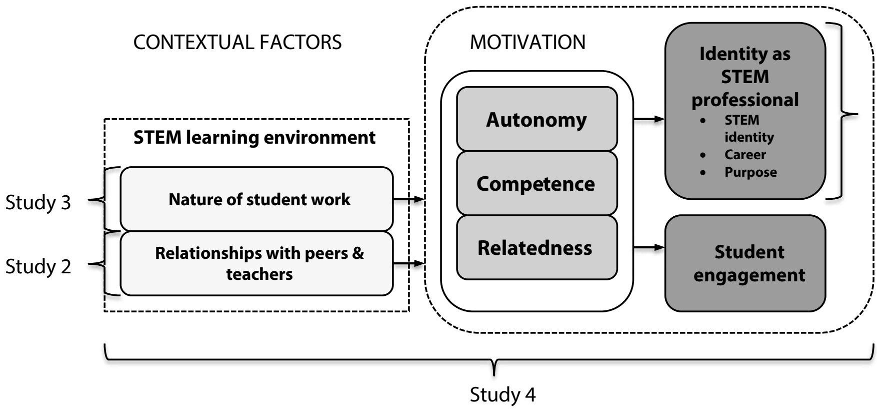



**Figure 3:** A self-determination theoretical model of motivational processes in STEM classes (Skinner et al., 2017)

According to this model (Figure 3), there are two main contextual factors within the STEM learning environment that predict students' sense of autonomy, relatedness, competence, and thus, in turn, their motivation and engagement in STEM. These contextual factors are: (1) the nature of student work and (2) the supportiveness of students' current relationships with classmates and the teacher, which we discuss in more detail later. Moreover, beside engagement, Skinner et al. (2017) also include the concept of 'identity as a STEM professional' as an important motivational outcome in the model.

*The nature of student work in STEM*

Skinner and colleagues (2017) argue that students' engagement can be fuelled by student work that is 'hands-on, heads-on, experiential, project-based, authentic, relevant, progressive and integrated across subject matter' (p. 2437). iSTEM education matches the requirements of this type of student work. We assume that iSTEM education provides more opportunities to fulfil students' basic psychological needs and will therefore increase students' engagement, as the approach is more student-centred compared to 'traditional' learning environments such as the lecture. iSTEM requires frequent collaboration with peers, which might fulfil students' need for relatedness. Also, the iSTEM approach intends that students have a degree of freedom to make choices during their learning process. For example, students who are free to a certain degree to decide how they design a rehabilitation device might feel more autonomy, more motivated and more competent as there can be more than one answer to solve the problem. Several studies confirm that student-centred STEM learning environments support students' engagement (Wu & Huang, 2007; Gasiewski et al., 2012; Hampden-Thompson & Bennett, 2013), but the significance of iSTEM for students' engagement remains unclear. It could be that the specific integrated nature of iSTEM is also significant for students' engagement.

*Relationships with teachers and peers*

Supportive relationships with teachers and peers are included in the model of Skinner et al. (2017) as a second contextual factor in the STEM learning environment that supports students' motivation and engagement. Other quantitative studies have shed light on the teacher's role, and more specifically the importance of their style, for motivating students' engagement, in terms of supporting their students' basic psychological needs (Stroet, Opdenakker, & Minnaert, 2013). SDT literature states that teachers can satisfy students' need for autonomy by providing them with choices and explaining the relevance of learning activities (Stroet et al., 2013, Skinner et al., 2017) and using informational language (Reeve et al., 2004). Teachers can nurture students' need for relatedness by fostering caring relationships (Skinner et al., 2017). Finally, the need for competence can be fulfilled by providing structure through, for example, providing students with constructive feedback and sufficient guidance during learning activities (Stroet et al., 2013). Several studies found evidence of the importance of teachers' support for students' basic psychological needs for their motivation and engagement in a STEM educational context (e.g. Valås. & Søvik, 1994; Black & Deci, 2000; Lavigne, Vallerand, & Miquelon, 2007; Hofferber, Basten, Großmann, & Wilde, 2016). Nevertheless, all these studies focus on one singular STEM subject and some investigate solely the importance of support for autonomy.

Until now, no study has investigated the relationship between teachers' support for students' basic psychological needs and students' motivation and engagement within the context of several STEM subjects, including iSTEM.

Regarding relationships with peers, Skinner et al. (2017), argue that peers are supportive to the extent that 'they include, connect with, listen to, and work constructively with others, both inside and outside the classroom' (p. 2437). As for the teacher's role in students' engagement in STEM, no research investigated – to the best of our knowledge - the significance of this aspect for students' engagement in STEM.

Finally, it remains unclear which contextual factors in the STEM learning environment are most meaningful for students' engagement from the student's point of view, as most research on this topic is quantitative. As we argue that the contextual factors that are considered to be the most meaningful by the pupils themselves, will probably affect their engagement the most, more qualitative research is required.

*Identity as a STEM professional*

Skinner et al. (2017) argue that engaged students will, over time, 'cement a valuable internal motivational resource, namely, a strong identity as a scientist – which combines a personal science identity with future plans for a career involving science and a sense that science serves important societal purposes' (p. 2437-2438), through their active engagement, persistence and success in STEM classes. They specify that students' identity as a scientist consists of three components, namely: a science identity, purpose in science and science career plans. First, a science identity refers to 'students' deeply held views of themselves and their potential to enjoy and succeed in STEM classes and careers' (Skinner et al., p. 2437). As the definitions of 'identity as a scientist' and 'science identity' do not only relate to the field of science, but also to the broader STEM field, we refer to this as 'identity as a STEM professional' and 'STEM identity'. Second, purpose in science, on the other hand includes students' belief that STEM course work and professions are relevant and important. Third, science career plans obviously refer to whether students view STEM as a key element of their vocational aspirations (Skinner et al., 2017).

In sum, according to this model, students' identity as a STEM professional is considered an outcome of engagement. However, from an SDT perspective we can also assume that the more students' identify with the nature of the student work in STEM and the work of STEM professionals, the more engaged they will be in the STEM learning environment, which in turn will lead to more potential long-term engagement in STEM education and careers. Indeed, SDT states that a more autonomous type of motivation[2] will apply to an individual, if there is congruence between that individual's personal values and the behaviour that individual expresses (Ryan & Deci, 2000; Soenens & Vansteenkiste, 2011), which is assumed to lead to higher emotional and behavioural engagement.

2 See chapter 2 - Figure 1 'the motivation continuum' - for a complete overview and explanation of different types of motivation.

A recent theory that covers the role of STEM identities for students' engagement in STEM education and career, and gains attention, is Goal congruity theory. This theory posits that an important aspect of the decision to pursue STEM for study or a career is the perception that those careers do not fulfil social (working with people) and societal (serving or helping others) interests. Research in Flanders found that students who pursue a hard science study or career (HS-choosers) express less social and societal interest than students who do not pursue such a study or career (NHS-choosers) (Boeve-de Pauw, Van Petegem, & Lauwers, 2014). Research to investigate the interest gap between HS-choosers and NHS-choosers is required to discover whether students have realistic perceptions of the social and societal orientation of hard science careers, or whether students' social and societal interests vary.

## Aims and outline of the dissertation

The theoretical framework of Skinner et al. (2017) provides important insights regarding the contextual factors in STEM learning environments that are significant for students' engagement. However, new ideas about how STEM should be taught and learned - such as the iSTEM approach – have appeared which demand a more complex conceptual understanding of student engagement and research into the contextual specificity of student engagement in STEM (Schmidt, Rosenberg, & Beymer, 2018). Moreover, to expand on efforts to validate the SDT theoretical model of motivational processes in STEM classes, additional data sources, such as qualitative student interviews and classroom observations are needed (Skinner et al., 2017). In this dissertation we aim to build further on the current research regarding student engagement in STEM by addressing the following research aims:

- Unravel the aspects or 'ingredients' that support and facilitate students' collective and individual engagement within iSTEM learning environments as well as conventional segregated STEM learning environments.

- Gain a deeper insight in how students' engagement occurs in relation to their interactions with others and contextual factors within diverse STEM learning environments.

- Deepen our understanding of motivational processes in STEM learning environments, by investigating the relationships between important motivational concepts.

We address these research aims throughout the studies in the various chapters of the dissertation[3].

3 As every study in each chapter can be read separately, overlap between the different studies occurs.

### *Study 1: 'Hard science': a career option for socially and societally interested students? Grade 12 students' vocational interest gap explored.*

The focus of this study relates to students' STEM identity. The starting point is the fact that (Flemish) students who do not study hard science at university, have more interest in 'working with people' (social orientation) and in 'serving or helping others' (societal orientation), compared with their counterparts who choose hard science. To explore this interest gap, we conducted an investigation based on 6 focus groups with a total of 58 Flemish grade 12 students. The aim was to investigate whether they had clear and nuanced perceptions about the social and societal orientation of hard science careers. We also explored the students' social and societal interests. From this investigation we gained an insight into why students with high social and societal interests can (not) identify with STEM and how we could possibly engage some of them in the field of hard science.

### *Study 2: Teacher's motivating style, students' motivation and engagement in STEM: the relationship between three key educational concepts.*

In the second study we investigated the importance of the teacher's role on students' motivation and collective classroom engagement in different STEM learning environments. Specifically, we investigated the significance of the teacher's support for the students' basic psychological needs (autonomy, relatedness and competence). Sinatra et al. (2015) refer to this as a context-oriented approach to study engagement, because the focus is on capturing characteristics in the social context and observing how they afford or impede engagement. To assess teachers' motivating style and students' engagement, we videotaped 30 classroom observations in different STEM lessons (physics, mathematics, engineering and iSTEM) in the 9$^{th}$ grade. The students' motivation was assessed at the end of the school year using an online questionnaire. The study provided us with an insight into what type of support for students' basic psychological needs was most crucial for their motivation and engagement in STEM and broadened our understanding of the relationship between the concepts of motivation and engagement.

### *Study 3: Students' engagement in different STEM learning environments: integrated STEM education as promising practice?*

In this study we also applied a context-oriented approach to investigate engagement (Sinatra et al., 2015). We specifically focused on the nature of student work in diverse STEM learning environments. We aimed to investigate the significance of iSTEM and the role of the STEM learning environments' stundent-centredness on students' collective classroom engagement. We analysed 24 videotaped classroom observations in both iSTEM and conventional STEM learning environments (physics and mathematics) and seven focus groups with 67 grade 9 students. The results provided us with some insight into which specific aspects regarding the nature of student work in STEM learning environments are most important for supporting students' engagement. Moreover, this study illustrated how students' engagement occurs within these diverse STEM learning environments.

### *Study 4: Understanding student engagement in STEM learning environments: a multiple case study.*

In the fourth study, we took a different perspective to studying students' engagement in STEM and in contrast to the second and third study, we focused on students' individual engagement and applied a 'person-in-context' perspective. This implies a more 'holistic' approach to understanding and describing how students interact with others, as well as with the dimensions afforded by the social context (e.g. classroom instruction) and how a particular type, level or form of engagement occurs (Sinatra et. al, 2015). We conducted a multiple case study and followed ten grade 9 students over the course of one complete academic year. Students who followed an iSTEM curriculum and those who followed a traditional STEM curriculum were both included. We collected data from interviews and logbooks. The results reveal several factors that are critical for (changes in) students' engagement in STEM learning environments, from the students' point of view.

## Overview of research methods

In conclusion, in this dissertation we investigated students' engagement in STEM and several contextual factors in the STEM learning environment from different perspectives that either support or constrain it (see Table 1). First, we approached the concept engagement collectively, individually and from an identity perspective. Second, we applied various quantitative and qualitative research methods, which allowed us to gain a deep understanding of students' engagement in STEM and the significant contextual factors that support or constrain them. Videotaped observations allowed us to gain insight into the significant factors within STEM learning environments that support students' classroom engagement. The qualitative data enrich the quantitative findings in this dissertation based on students' narrative experiences. These findings allowed us to gain an insight into how students' engagement manifests itself in relation to various contextual factors in the STEM learning environment and increases the validity of the quantitative data.

**Table 1:** Conceptual approach of engagement and research methods in the different studies

| | **Study 1:** *'Hard science': a career option for socially and societally interested students? Grade 12 students' vocational interest gap explored.* | **Study 2:** *Teacher's motivating style, students' motivation and engagement in STEM: the relationship between three key educational concepts.* | **Study 3:** *Students' engagement in different STEM learning environments: integrated STEM education as promising practice?* | **Study 4:** *Understanding student engagement in STEM learning environments: a multiple case study.* |
|---|---|---|---|---|
| **Conceptualization engagement** | STEM identity approach | Collective engagement | Collective engagement | Individual engagement |
| **Approach** | / | Context-oriented | Context-oriented | Person-in-context |
| **Research method** | Focus groups | Videotaped observations | Videotaped observations + focus groups | Interviews + logbooks |

# CHAPTER 2

2

# Study 1:
## ‘Hard science’: a career option for socially and societally interested students? Grade 12 students’ vocational interest gap explored.[4]

4 This chapter is based on: Struyf, A., Boeve-de Pauw, J. & Van Petegem, P. (2017). ‘Hard science’: a career option for socially and societally interested students? Grade 12 students’ vocational interest gap explored. *International Journal of Science Education, 39*(17), 2304-2320.

## Abstract

A key theme in science education research concerns the decline in young peoples' interest in science and the need for professionals in hard science. Hard science typically includes technology, engineering, mathematics, physics and, to some extent, chemistry. Goal Congruity Theory posits that an important aspect of the decision whether to pursue hard science for study or as a career is the perception that hard science careers do not fulfil social (working with people) and societal (serving or helping others) interests. In this qualitative study, we explore grade 12 students' perceptions about the social and societal orientation of hard science careers. Furthermore, we investigate the variation in students' social and societal interests. Six focus groups were conducted with 58 grade 12 students in Flanders. Our results indicate that students hold very variable perceptions about hard science careers' social orientation. A number of students hold stereotypical views, while others believe cooperation with others is an important aspect of hard science careers nowadays. Students with clear perceptions often refer to role models, such as parents. Furthermore, our results show that students believe hard science careers can be societally oriented in the sense that they often associate them with innovation or societal progress. Finally, our results indicate that students may differentiate direct versus indirect societal orientation. These findings contribute to literature regarding social and societal interests and students' perceptions of hard science careers' social and societal orientation.

## Introduction

Over the past decade, a key theme in science education research has been the decline in young people's interest in science (Bøe, Henriksen, Lyons & Schreiner, 2011; OECD, 2008a). Several reasons underlie the importance of placing students' declining interest in science high on the research agenda. One reason is society's need for critical and scientifically literate citizens who are aware of how science and technology increasingly play a role in contemporary society (Osborne & Collins, 2001; Schreiner, 2006). Another reason is the need for professionals in hard science, rather than professionals in soft science careers (Bøe et al., 2011; OECD, 2008a). The latter covers biology and health issues, while hard science typically includes technology, engineering, mathematics, physics and, to some extent, chemistry (Kjærnsli & Lie, 2011; Schreiner & Sjøberg, 2007). From an economic perspective, there is a need for hard science professionals (e.g. scientists, engineers, technicians, computer scientists) in order to maintain economic growth (Schreiner, 2006). From an ecological or social perspective, hard science experts are necessary to tackle society's contemporary problems (e.g. combating environmental degradation and pollution, developing renewable energy, ensuring safe and affordable food) (Carlone et al., 2015; Kjærnsli & Lie, 2011). Whichever argument is placed at the centre of this debate, the issue of declining interest in science and the related decrease in students enrolling in higher science education and hard science careers is pressing, and at the core of policy, practice and research worldwide.

To build scholarly understanding of students' (dis)interest in the pursuit of hard science study or a career, extensive research regarding this topic has been carried out (Bøe et al., 2012). Interestingly, recent studies found different interests between students who pursue a hard science study course or career (HS-choosers) and students who do not pursue this (NHS-choosers). Different interests are found especially with regard to social and societal orientation (Authors, 2014; Diekman et al., 2016). 'Social orientation' is defined as 'working with people' whereas 'societal orientation' refers to 'serving or helping others' (Diekman et al., 2016). In particular, NHS-choosers express more interest in both social and societal orientation in comparison with HS-choosers. The concepts of social and societal orientation are captured by other authors under the concept 'people-orientation' (Masnick, Valenti, Cox & Osman, 2010; Morgan, Isaac & Sansone; 2001; Su & Rounds, 2015) and 'communal orientation' (Brown, Thoman, Smith & Diekman, 2015; Diekman, Brown, Johnston & Clark, 2010; Diekman, Steinberg, Brown, Belanger & Clark, 2016). In this paper we differentiate between social orientation, on the one hand, and societal orientation, on the other hand, to maintain each concept's specific nature.

The interest gap between HS-choosers and NHS-choosers regarding social and societal orientation is the starting point of this study. The question arises as to whether students are holding realistic perceptions regarding hard science careers' social and societal orientation, or if students' social and societal interests vary. In this study, this social and societal interest gap will be explored.

### *Vocational interests: Holland's RIASEC model*

Interest is commonly defined as comprised of two different components: situational interest and individual interest (Dierks, Höffler, Blankenburg, Peters & Parchmann, 2016). The first emerges as a momentary psychological state as a result of one's interaction with the environment. The latter refers to a person's enduring and often stable disposition. Individual interest is the most important aspect regarding educational or vocational choices (Hidi, 2006; Renninger, 2000). It is a critical predictor for choice of study and career choice (Boeve- de Pauw, Van Petegem & Lauwers, 2014; Morgan et al., 2001; Su & Rounds, 2015).

A commonly studied typology used to categorize individual interests in a vocational context is Holland's RIASEC model (acronym of *Realistic, Investigative, Artistic, Social, Enterprising and Conventional*) (see e.g. Dierks et al., 2016 and Su & Rounds, 2015; Holland, 1997). Each of the six categories captures a specific individual interest and corresponding features in work environments (Holland, 1997; Su & Rounds, 2015). In the context of this paper, the RIASEC model is very relevant as it is also applicable within a science context specifically. Dierks et al. (2016) used this model to categorize interest profiles in science-related activities. Moreover, the social (S) category within this model captures both *social* (working with people) and *societal* (serving or helping others) vocational interests.

Most importantly, Holland's theory asserts that the preference for a certain study area or career will be greater if there is congruence between a person's individual interests and the individual's perception that a certain work environment will match these interests (Holland, 1997; Nauta, 2010). Thus, with regard to such a person-environment fit theory, individuals identify career options by assessing the compatibility of these occupations with their self-image (Gottfredson, 1996). This process is closely interwoven with an individual's identity construction (Bøe et al., 2011; Holmegaard, Madsen & Ulriksen, 2014; Schreiner & Sjøberg; 2007).

### *The role of perceptions about hard science careers' social and societal orientation*

A recent person-environment fit theory, which specifically focuses on social and societal vocational interests, is the Goal Congruity Theory (Diekman & Steinberg, 2013; Diekman et al., 2016). This theory posits that an important aspect of the decision whether to pursue a hard science course of study or career is the perception that hard science careers do not fulfil social and societal interests (Diekman & Steinberg, 2013). Diekman et al. (2010) found evidence for the assumption that hard science careers are perceived to be less likely to afford social and societal interests. A study of Masnick et al. (2010) on American students' attitudes about science careers found similar results. American students believe science careers and technological occupations to be less 'people-oriented' compared to other popular career choices (Masnick et al., 2010). Nevertheless, 'people orientation' is not defined in the latter study, thus is not clear if this concept includes both social and societal orientation.

A number of studies that investigated students' educational choices in depth indicate that students associate hard science professions with stereotypical views regarding its social orientation (Clarke & Teague, 1996; Cleaves, 2005; Holmegaard et al., 2014), such as 'to be stuck in an office with just a computer' (Clarke & Teague, 1996, p. 243).

Interestingly, Brown et al. (2015) found that perceiving hard science careers as affording greater social and societal orientation is associated with greater interest in hard science careers. A study of Steinberg and Diekman (2016) indicates furthermore that learning environments can impact perceptions about hard science professions' social and societal orientation. Individuals who report greater social and societal experiences in their education are more likely to perceive hard science careers as socially and societally oriented (Steinberg & Diekman, 2016).

### *Hard science careers' social and societal orientation*

Hard science occupations originally fell within the Investigative (activities connected to intellectual tasks) and Realistic (activities connected to practical tasks) dimension of Holland's RIASEC model (Dierks et al., 2016; Holland, 1997; Su & Rounds, 2015). However, this focus on solely intellectual and practical activities no longer represents the broader contemporary spectrum of hard science-related activities (Dierks et al., 2016). Several researchers highlight the importance of social orientation for the vast majority of hard science professions in today's workplace, where teamwork is an important part of daily reality (Scutt, Gilmartin, Sheppard & Brunhaver, 2013; Seat, Parsons & Poppen, 2001). Collaboration and communication skills are important for twenty-first century engineers and scientists (Seat, Parsons & Poppen, 2001). Darling & Dannels (2003, p. 1) emphasize the importance of oral communication for engineers as, 'engineering practice takes place in an intensely oral culture and while formal presentations are important to practicing engineers, daily work is characterized more by interpersonal and small group experiences.' Also, science includes different social activities. It is no longer the 'prototypical individual working in a lab with goggles and a lab-coat' (Dierks et al., 2016, p. 239). Scientists are often involved in multi-disciplinary research projects or collaborate with industries or public institutions (Dierks et al., 2016). Hara, Solomon, Kim and Sonnenwald (2003) stress the importance of such collaboration for scientific research, as it is characterized by constantly evolving technologies and highly specialized domains of expertise. An individual scientist can rarely provide all the knowledge and resources necessary to cope with complex research problems. Hard science careers are also highly societally oriented, as they can have a great deal of impact on tackling contemporary social and ecological problems. Furthermore, it has become evident that hard science professionals not only need to consider technical needs during the development of new products and processes, but also social and ecological needs. Success of a new product or process is no longer guaranteed, even when it is perfect from a technical point of view (Stroeken & De Vries, 1995).

## Aim of the present study

The current study explores how grade 12 students in Flanders (the Dutch speaking community of Belgium) perceive hard science careers' social and societal orientation. Furthermore, this study explores the social and societal interests of these students. Flemish students in the 12th grade are facing the transition to higher education or the labour market. The focus in this study is on both HS-choosers and NHS-choosers, as well male as female, from classes with and without a strong focus on hard science. This leads to the following research questions:

- What perceptions do grade 12 students hold regarding hard science careers' social and societal orientation?
- In which way do social and societal vocational interests vary between grade 12 students?

The purpose of the first research question is to investigate if students have clear and nuanced perceptions about contemporary hard science careers' social and societal orientation. The aim of the second research question is to explore the concepts of social and societal interest, based on how grade 12 students express these interests.

## Method

### *Focus groups*

In order to gain deeper insight into (1) grade 12 students' perceptions about the social and societal orientation of hard science careers and (2) the variation in grade 12 students' social and societal vocational interests, the required data were essentially qualitative. Focus groups were chosen as the most appropriate qualitative data gathering method to answer our research questions. The fundamental aim of this methodology is to explore the range of attitudes, values and beliefs that are commonly held within a certain population (Vaughn, Schumm & Sinagub, 1996). In comparison to one-to-one interviews, the group context in a focus group offers a degree of support and security. The moderator stimulates individual respondents to share their ideas and to discuss with other group members in a non-threatening, relatively naturalized context (Kitzinger, 1995; Osborne & Collins, 2001). This can help individual respondents to explore and clarify their ideas in a way that would be harder to access in a one-to-one interview (Kitzinger, 1995). In total, six focus groups were conducted. The group size of each focus group ranged from 5 to 12 students, which is an appropriate group size (Osborne & Collins, 2001).

### *Participants and research context*

Participants in this study were Flemish grade 12 students, aged 17 to 18 years old. Students who obtain their secondary education diploma are free to choose their field of study in higher education. There is no common government-run exam in Flanders, except for medicine and dentistry (Buyse, Lievens & Martens, 2010).

Grade 12 students were sampled from four schools in Flanders, of which three schools were located in smaller urban areas. To provide a sample of students with different study and career aspirations, focus groups were held with randomly selected students in classes with and without a strong focus on hard science. Two focus groups were conducted with students from a science and mathematics track, two with students from an industrial sciences track and two with students from a commercial educational track.

Altogether, 58 students, of whom 37 were male, participated in the focus groups. All students planned to pursue study in higher education. Twenty-seven respondents were HS-choosers and 25 students were NHS-choosers. The six remaining students had not yet decided whether to pursue a hard or non-hard science study or career. Students were classified as HS-chooser or NHS-chooser based on their responses to an open-ended question about which higher education course or profession they planned to pursue. These responses were categorized using the classification of 'hard science' occupation of Kjærnsli & Lie (2011), which is based on the International Standard Classification of Occupations (ISCO-88) (see annex 10 in OECD, 2008b). Kjærnsli & Lie (2011) grouped the occupations below as 'hard science' occupations (the numbers refer to ISCO-88 codes):

1. 2100-2149: Physical, mathematical and engineering science professionals
2. 3110-3119: Physical and engineering science professionals
3. 3133 and 3193: Medical, optical and electronic equipment operators (Kjærnsli & Lie, 2011, p. 134).

Consequently, students in this study were considered as HS-choosers, if they were to pursue a study course or career in the field of hard science. Students who aspired to study or pursue an occupation that could not be classified as a hard science were considered to be NHS-choosers.

**Table 2.** Overview of focus groups and participants' aspirations (SM= Science and Mathematics; IS=Industrial Sciences; C= Commercial)

| Focus group (FG) | Educational track | HS-choosers | NHS-choosers | 'hesitating' students |
|---|---|---|---|---|
| **FG1-SM** | Science and Mathematics | 2 | 9 | 0 |
| **FG2-SM** | Science and Mathematics | 5 | 4 | 3 |
| **FG3-IS** | Industrial Sciences | 10 | 0 | 1 |
| **FG4-IS** | Industrial Sciences | 8 | 0 | 0 |
| **FG5-C** | Commercial | 1 | 4 | 0 |
| **FG6-C** | Commercial | 1 | 8 | 2 |

### *Procedure*

Focus groups were conducted at the end of school year 2014-2015, between May and June, and were moderated by the first author. A passive informed consent form was given in advance to the students and their parents, so they could decide whether or not to participate. During the introduction to each focus group, the researcher asked an active informed consent question to each participant.

The nature of the focus group was semi-structured. An interview guide was developed, including questions about educational and vocational interests and students' perceptions of hard science careers. The focus group started with the moderator's explanation of the general content, the confidentiality of the data and some focus group rules. Next, students presented themselves and talked about their choice of study for the upcoming year, their career aspirations and their most important reasons and interests for making these choices. Special attention was given to students' social and societal vocational interests. Two statements were used as a starting point of the discussion. The first statement covered social vocational interest: 'I want a profession which allows me to have a lot of social contact with others'. The second statement concerned societal vocational interest: 'I want a job through which I can help others and/or society'.

After this, students were asked to share their opinions and perceptions of hard science careers. The concept 'hard science profession' was made clear to the students as 'a profession in the field of science, technology, engineering and mathematics. Examples of hard science professions are a scientist, engineer, technician or computer scientist.' Students made associations with hard science careers by brainstorming. Then, there was a deeper discussion of students' perceptions regarding hard science careers' social and societal orientation. Students shared their opinions about two statements shown by the researcher: 'In technical and scientific professions you do not have much contact with other people' and 'Science and technology are important for society.'

### *Analysis*

Each focus group lasted for approximately one hour and was audio recorded. Next, the focus group data were analysed thematically using the six-step approach of Braun and Clarke (2006) (see also Holmegaard et al., 2014; Holmegaard, 2015). As a first step in the analysis process, focus group data were transcribed and the process of (re)reading began to enable more familiarity with the data. Simultaneously, notes of the initial ideas and reflections evoked by some fragments in the transcript were taken. From the second step in the analysis, the qualitative data analysis software Nvivo 10 was used to support the further analysis process. In this phase, initial codes were generated across the whole data set. Third, all the codes in the data set were gathered under broader codes that reflected key themes within the interview (e.g. students' vocational interests, students' associations with hard science careers, students' perceptions towards hard science careers' social orientation). Fourth, these themes were reviewed in relation to the coded fragments and the entire data set, resulting in a thematic map of the analysis. Fifth, the specifics of each theme were refined. Some themes were divided into smaller sub-themes. Sixth, vivid quotes of some respondents were selected and further analysed, relating back to the research questions and the literature (Braun & Clarke, 2006). The quotes reported in this paper use pseudonyms to protect the respondents' privacy.

## Results

Based on the analysis of the focus groups, students' perceptions about hard science careers' social and societal orientation will be discussed first. Next, the focus will be on the students' social and societal interests, how they expressed these interests and how they comprehend them.

### *Students' perceptions about hard science careers' social orientation*

A number of students perceived certain hard science careers as having a low social orientation. This perception reflects stereotypical views.

| | |
|---|---|
| Thomas: | Those [mathematicians] are nerds, who spend so much time on their own. |
| Interviewer: | Nerds who spend so much time on their own…? |
| Thomas: | Yes, that is the way I see them. They prefer to sit inside and be alone, instead of other things. |

(FG1-SM)

As a consequence, these stereotypes may lead students who have a strong social vocational interest away from hard science careers. One of the respondents did not see herself in future as a scientist, due to the perception that this is an 'isolated' profession. Instead, she imagined her 'future self' as a person who has a social career with lots of variety, which does not fit her perception of a scientist.

| | |
|---|---|
| Interviewer: | Do you see yourselves becoming scientists in future? |
| All: | (Laughing) |
| Sara: | Anyway not in a lab. |
| Interviewer: | Why not in a lab? |
| Sara: | It seems quite boring to me to be in your lab everyday, standing there in your lab coat and doing the same experiment everyday. I would not like that. It is also a bit unsocial, working in your little den, as I see it. I would prefer to do something social. |

(FG1-SM)

In contrast to these perceptions, most respondents in the focus groups believed that most hard science professionals, such as engineers, technicians and scientists, need to cooperate regularly with others. When students made associations with hard science careers, they often mentioned 'teamwork' or 'being social' as important skills for such careers. Furthermore, students did recognize and understand the value of teamwork and cooperation for hard science careers. They believed teamwork is necessary in order to solve complex research and design problems. In this sense, they are holding a view that matches today's workplace of engineers and scientists. As the next quote illustrates, students who were following an industrial sciences track in particular, could express their arguments for the necessity of hard science careers' social orientation well.

Frank: I wrote down 'problem-solving skills' and 'working in a team'.
George: Also a 'go-getter', because you are confronted with problems which are not directly solvable. Then you really need to hold on and not give up.
Interviewer: So that you need to keep on searching.
Frank: Yes, and that will also be better in a team, if you cooperate with some people.

(FG3-IS)

However, students who were following a science and mathematics track stated that they had only recently developed a more accurate image about hard science professions' social orientation.

Anna: I actually always thought that these technical professions and engineers were always alone: busy behind their computer, and yeah maybe from time to time in a meeting… I still have this idea a bit, but I understand that it is less than I thought. I really had the idea that it was much more lonely.
Interviewer: What do the others think about that?
Denise: I had this idea especially about professions in computing science.
(FG2-SM)

A discussion about hard science careers' social orientation in comparison with other professions appeared in one focus group. These students expressed the belief that every profession has its moments of isolation and that there is no difference regarding hard science careers' social orientation compared to other professions. One student argued that hard science professions are less socially oriented compared to other professions, for example, in the health care sector.

Catarina: But every profession has moments, … A teacher for example; one moment he's sitting in front of the class, social contact. Then later on he has to correct assignments, which will take hours alone behind a desk. I think that you have both in each profession.

Interviewer: So that you have just a kind of variety?
Catarina: Yes, if you go to work in the healthcare sector, yes then you will have of course more contact with people.
Maryam: But also there, you may even have to do administration and stuff, so …
Catarina: And as a writer you are also often writing behind you desk.
(FG2-SM)

### *Students' perceptions about hard science careers' societal orientation*

All students in each focus group agreed with the statement that science and technology are important for society. They often associated hard science careers with 'innovation', 'societal progress', and thus as an important aspect of society's future or economy. Students often mentioned, in their examples, the instrumental value of hard science: e.g. the role of hard science in developing new things, games, computers, machines and cars.

Sara: You need science and technology for everything, really for everything.
Joe: Otherwise this school would not be standing here for example. Calculations were made for that.
John: Practically everything. Otherwise we would be still busy making a fire in the cave.
Joe: For almost everything we do electricity is needed, and if there are no people like that [hard science professionals] and something breaks down, then we would be thrown back to the Middle Ages.
John: Ranging from medical aspects to the environment.
(FG5-C)

In contrast with the quote above, students rarely illustrated the relevance of hard science in meeting society's social and ecological needs spontaneously. Only one other respondent mentioned explicitly that engineers help society, by searching for solutions for environmental problems.

Few students mentioned perceptions of the negative effect of hard science in society. One respondent made the remark that hard science is good for society when it is used in the right way.

| | |
|---|---|
| Richard: | Yes, science and technology are important for society, but you have to take into consideration the right use of science and technology. Once they developed an atom bomb and that was not really pleasant. |
| (FG3-IS) | |

Despite the fact that these students found hard science careers important for society, some students made the remark that hard science careers' social orientation depends upon the job content.

| | |
|---|---|
| Interviewer: | Do you have the feeling that you can help people in the job you will do or not? |
| William: | A little bit. It depends what. If you are for example an industrial engineer and you end up somewhere in a company that is doing something for people, or you just develop luxury products; that's a big difference. |
| (FG4-IS) | |

## *Students' social and societal interests*

### *Social interest*

NHS-choosers, who were often in a science and mathematics or commercial educational track, often mentioned social orientation as one of their most important vocational interests. HS-choosers, in contrast, mentioned other interests prompting them to opt for a hard science study course in higher education or a hard science career: content interest, practical-oriented interest and extrinsic interests (e.g. high salary, job security). However, most HS-choosers agreed with the statement, 'I want a profession which allows me to have a lot of social contact with others'. Many HS-choosers and NHS-choosers indicated that they did not want to end up alone behind a desk. Nevertheless, this statement caused confusion for many of the HS-choosers. While answering the statement, they began to imagine whether social contact in their future hard science career was possible or necessary, instead of reflecting on their own interest. They stated that social orientation is self-evident, and that it is nearly impossible to have no social contact in a professional work context. This illustrates that HS-choosers did not necessarily find social orientation unimportant, but they seemed to consider social interest as secondary in comparison to other interests.

| | |
|---|---|
| William: | You have to deal with your colleagues. |
| Bjorn: | But it also depends which profession you will enter, because most of the time you will have people working for you. For example, you need to tell them what to do, like improving the security. |
| Interviewer: | But how important is this for you personally? |
| Bjorn: | It depends in which sector you are working. |
| William: | It is important to be able to communicate. |
| Max: | That you are not sitting there alone the whole day. |

(FG4-IS)

For a few respondents, social orientation in their future career was unimportant or even not favourable. A student, from a commercial educational track, mentioned a preference for as few people as possible in her future occupation: 'I do not like fuss, I prefer to be on my own'. This implies that the perception of an occupation as being highly socially oriented may be a threshold for certain students when deciding to pursue such a career.

*Societal interests*

NHS-choosers in the focus groups often spontaneously mentioned societal interest next to social vocational interest. Examples of the study or career aspirations of these students are: medicine, pharmaceutical sciences, obstetrics, and teaching. For some of these students helping people or children is a childhood dream.

Interestingly, some students made a distinction between directly helping people and indirectly helping people. A discussion in the focus group between two respondents who both placed value on societal interest, illustrates this. One of these students aspired to a future career that allows direct social contact with her patients, while the other student preferred to help people indirectly.

| | |
|---|---|
| Lenore: | I maybe would like also to… I don't know of course, to do research about new medication or something like that. But I would also like to have personal contact with this person, to help that specific person get better. |
| Cindy: | I would personally prefer to do something for the whole of society, yes, in general. |

(FG1-SM)

Helping people indirectly was satisfying enough for the respondent who sought to pursue study in the medical sciences. The other student argued that she perceived hard science careers' societal orientation as more 'indirect', which did not match her own 'direct' societal-oriented interest. Actually, she aspired 'social orientation' within 'societal orientation' as the latter and the next quote illustrate.

| | |
|---|---|
| Lenore: | I find it in a way more indirect [engineering]. I also just want social contact and I think you also have this as a scientist, but that is just with your colleagues talking about your job. While if you are, for example, a doctor, you can talk with people about private things. |

(FG1-SM)

HS-choosers rarely mentioned societal interest spontaneously. After being shown the statement, 'I want a job through which I can help others and/or society', one HS-chooser mentioned that reflecting on the social orientation of a future career is actually important for him.

Other HS-choosers and NHS-choosers did not necessarily place value on the social orientation of their future career. They perceived social orientation in a profession more as something self-evident. One HS-chooser argued that he did not like 'to see other people put down'. Other students had simply not reflected on this before, as it is not their priority or main interest.

| | |
|---|---|
| Anouk: | I don't know, I would like to do that [helping people/ society], but I don't really know it for sure yet… It is not that I am now really like 'I want to make the world a better place'. I just want to decide first what I am going to study and after that I can still do something with it. |
| (FG5-5C) | |
| Thomas: | I think most of us, or at least me, would rather choose based on what they like to do. It is positive if you help society with it, but I do not think that someone will specifically say 'Ah I want to help society, so I am going to do that [study/ occupation]. |
| (FG1-SM) | |

## Discussion

This study explored Flemish grade 12 students' perceptions about hard science careers' social and societal orientation. The aim was to investigate whether students who are facing the transition to higher education have nuanced or accurate perceptions. Furthermore, the aim was to obtain more insight into social and societal interests. Therefore, we aimed to explore the social and societal interest gap between HS-choosers and NHS-choosers.

### *Students' perceptions about hard science careers' social and societal orientation*

Based on the analysis of the focus groups, we found that students' perceptions about hard science careers' *social orientation* vary. In line with previous studies on students' educational choices (Clarke & Teague, 1996; Cleaves, 2005; Holmegaard et al., 2014), the results in this study suggest that stereotypical views regarding hard science careers' social orientation also exist among students in Flanders. A number of Flemish grade 12 students in the focus groups, perceived hard science careers as 'isolated'. As the data suggest, these stereotypes may lead students who have strong social interests away from such careers. This is a matter of concern, within the context of society's need for hard science professionals. Furthermore, students need accurate information about occupations to make a well-considered choice of study.

In contrast to these findings, most grade 12 students in the focus groups have a more accurate and realistic view regarding hard science careers' social orientation. A number of students, for example, did not believe that hard science careers are necessarily less socially and societally oriented than other professions, such as teachers or writers. This is interesting, as in the study of Masnick et al. (2010) teachers and writers were perceived as people-oriented by American students, while hard science careers were perceived as not people-oriented. Furthermore, participants in this study often mentioned 'teamwork' or 'being social' as important aspects or skills for hard science careers. These perceptions match the reality of hard science careers' activities nowadays. Students from the industrial sciences track, in particular, could express their arguments for the necessity of hard science careers' (e.g. engineering) social orientation well. This may be due to the fact that these students have already had more experiences with social and societal activities in their education (e.g. working in groups on an 'engineering project') (see Steinberg & Diekman, 2016), compared to their counterparts in a science and mathematics or commercial track. Students in the science and mathematics track reported that they had recently gained more accurate perceptions about hard science professions (e.g. engineering, computer science). They stated that information sessions regarding different study choices and occupations helped them to gather more accurate information about hard science careers. Consequently, such information sessions may help students to create more accurate images of hard science professions' social and societal orientation.

| | |
|---|---|
| Rebecca: | I absolutely did not know in the 11th grade what an engineer does for example. |
| Cindy: | It is only since the 12th grade that we have got an idea about it. There are always student who know already what they want to study, but really knowing what these studies are about… It's also because our minds were busy with it, everyone was like 'oh, I want to know already what this is all about', because it is all coming closer. |

(FG1-SM)

| | |
|---|---|
| Anna: | I think that it is just because recently we have been busy with this choice of study, and we also visited these different study options, and then you see people who are busy with it. Then you realize that those stereotypes are actually less true. |
| Maryam: | Yeah, they break down when you see who is standing there. |

(FG2-SM)

Although it was not the focus of this study, our results not only show the impact of information sessions, but they also underscore the importance of role models, such as parents, in shaping accurate and nuanced perceptions about hard science careers' social orientation. Across the focus groups, students who have clear and nuanced perceptions about hard science professions and their social orientation, refer to role models like parents or other family members, who have a hard science career.

Alfred: My dad works in the IT-sector and he has days that he is just strumming behind his computer, and he has to do things. And other days he is also busy all the time discussing with other people. But it really depends on what is needed… Sometimes he's sitting the whole day behind his computer, and sometimes he walks around and he goes to a meeting with other people or there are other people who come to ask him 'what did you do?' … And then he has to show what he has already done.

Barbara: Yes, my parents also have to go to a lot of conferences. Then you come automatically into contact with other people from all over the world who are talking about the same thing.

Interviewer: And what are your parents doing?

Barbara: They need to work with engineers etc. They studied mathematics, but … they actually have to make applications.

(FG2-SM)

Students' beliefs about hard science careers' *societal orientation* are mostly positive, in the sense that they believe that these professions create progress for society. Nevertheless, a few students mentioned the role of hard science careers in combating social and ecological problems. This finding supports the work of Osborne and Collins (2001) who conducted focus group discussions with 16-year-old pupils in London about their views of the role and value of science education. In their comments, students expressed the general value of science in society, often illustrated with examples of its instrumental value, for example the use of washing machines.

The results suggest that helping students to create a clear view about hard science careers and their social and societal orientation at an earlier stage of their process of study choice would be useful, as some students had only recently developed an accurate image of hard science careers and their social and societal orientation. As the results in this study have shown, close role models, such as parents, can impact students' perceptions through the information they provide. Nevertheless, schools can also have a greater role in providing accurate information about hard science careers' social and societal orientation.

Teachers can, for example, visit hard science professionals' work places with their class or can invite hard science professionals to their school.

In addition, schools can highlight the social and societal orientation of hard science careers through the education they provide. This may arouse the interest of students who have strong social and societal interests. Schools can therefore implement (hard) science programmes that apply social and societal activities in science. Although science education programmes may vary in content, scope and strategy they often provide opportunities through facilitating collaborative student work and by applying hard science to solve 'real-world' problems (e.g. Goovaerts, De Cock & Dehaene, 2016; Diekman et al., 2016).

In this study, students' perceptions were investigated at one moment in time. Future research can specifically focus on how students' perceptions about hard science careers' social and societal orientation evolve. Some students suggested that their ideas about hard science careers' social and societal orientation developed or changed over time. Mapping this developing process qualitatively would give more insight into factors that impact students' perceptions about hard science careers' social and societal orientation. Investigating this process would be especially valuable to test the effectiveness of educational interventions that aim to improve students' perceptions about hard science careers' social and societal orientation.

### *Students' social and societal interests*

NHS-choosers in the focus groups often mentioned social and societal interest as an important vocational interest, while HS-choosers mentioned other interests, such as practical interest. When we explored social and societal interest explicitly, HS-choosers did not express the view that they found this interest unimportant, but they expressed it more as something self-evident. A possible explanation is that a profession's social and societal orientation can be seen as a person's basic psychological need for satisfaction of relatedness (Brown et al., 2015; Diekman et al., 2010; Morgan et al., 2001; Ryan & Deci, 2000). However, there was one student who particularly expressed a preference for having the least possible social orientation in her future career. The differences in social and societal interests between HS-choosers and NHS-choosers, on the other hand, could be partly explained by the fact that NHS-choosers are more likely to be female (Diekman et al., 2016). Women are more socially and societally oriented, in contrast to men who are more interested in working with things (Eccles, 1994; Morgan et al., 2001; Su & Rounds, 2015; Su, Rounds & Armstrong, 2009).

Interestingly, the results also show that students can express a very specific *'direct'* or *'indirect' societal interest*. Some students preferred to help or serve other people in a direct way (e.g. a doctor who helps a patient during a visit), while other students preferred to help others in an indirect way (e.g. developing new medicines). Thus, students with a 'direct' societal interest will be probably less likely to pursue a hard science career. We also found evidence that the concept of social orientation, on the one hand, and societal orientation, on the other hand, may be perceived by students as two different concepts which do not necessarily overlap.

Maryam: You can help society and people, but you may not necessarily come directly into contact with people during your work. Because if Anna ends up behind her computer, it may be possible that she is helping other people. It does not necessarily mean that someone is sitting beside her while she is on the laptop, whom she can have contact with all the time. Thus I don't know, I find that something else.

(FG2-SM)

These findings give greater support to the proposal of dividing the concepts in future research into (1) social and societal orientation/ interest (2) 'direct' and 'indirect' societal interest. The 'social' dimension of Holland's RIASEC model, for example, focuses more on directly helping others (Dierks et al., 2016), while it would be valuable to broaden this dimension to 'indirectly' helping others. Splitting up these different concepts would also enrich Goal Congruity Theory.

A limitation of this study is that students' individual social and societal interests could not be linked to their individual perceptions regarding hard science professions' social and societal orientation. Due to the nature of the focus group method, it was not always clear during the transcription of the focus groups which participant had made particular statements, as the focus groups were not videotaped. This study served as an explorative study. Future research can conduct one-to-one interviews or surveys, in order to link the concepts, individual interests and individual perceptions, to each other. This would enable the further investigation of whether individuals who value social and societal interest may be led away from hard science careers.

## Conclusion

The present study found that Flemish grade 12 students' perceptions about hard science careers' social and societal orientation vary. A number of students in the focus groups expressed stereotypical views and believed hard science careers to be 'isolated'. In contrast to these findings and earlier findings, most grade 12 students held nuanced and realistic perceptions about hard science careers' social and societal orientation. Furthermore, this study found that NHS-choosers expressed more social and societal interest. Although HS-choosers found social and societal interests not unimportant, but rather self-evident. Evidence was also found that students may distinguish social orientation, on the one hand, and societal orientation, on the other hand, and express an interest in 'directly' versus 'indirectly' helping others. These insights can contribute to and enrich Holland's RIASEC model, Goal Congruity Theory and related literature on students' perceptions about hard science careers' social and societal orientation.

# CHAPTER 3

# Study 2:

## Teachers' motivating style, students' motivation and engagement in STEM: The relationship between three key educational concepts.[5]

5 This chapter is based on: De Loof*, H., Struyf*, A., Boeve-de Pauw, J., & Van Petegem, P. (2019). Teachers' motivating style and students' motivation and engagement in STEM: The relationship between three key educational concepts. *Research in Science Education*. https://doi.org/10.1007/s11165-019-9830-3

## Abstract

A key theme in the science education literature concerns the increasing 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.

## 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).

### *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).

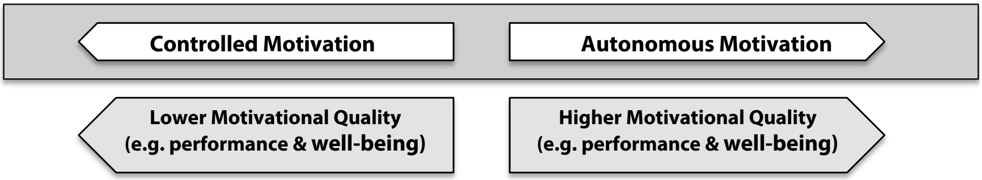
*Autonomy refers to "…being the perceived origin or source of one's own behavior"* (Deci & Ryan, 2002, p. 8). Applied in an educational context, students will experience autonomy when they perceive their engagement in learning as being their own choice, reflecting their own interests and values (Stroet, 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.

### *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 of punishments<br>- Compliance<br>- Reactance | - Ego involvement<br>- Focus on approval from self and others | - Personal importance<br>- Conscious valuing of activity<br>- Self-endorsement of goals | - Congruence<br>- Synthesis and consistency of identifications | - Interest<br>- Enjoyment<br>- 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.

### *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.

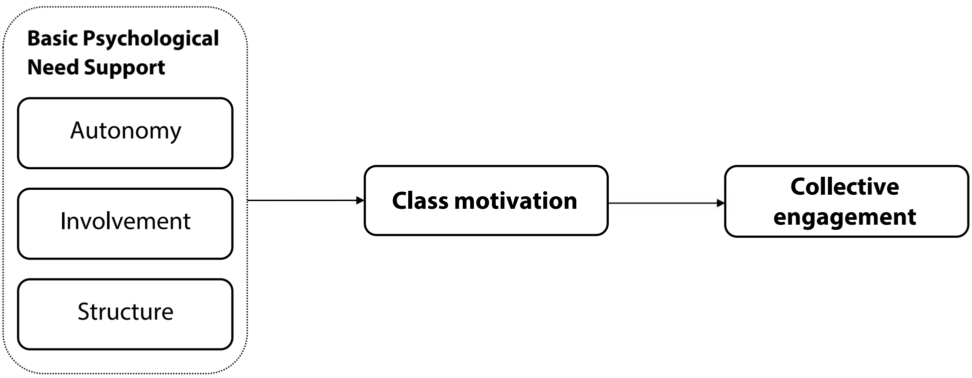



**Figure 2.** Link between basic psychological need support, class motivation and collective engagement.

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.

### *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.

## Method

### *Participants and research setting*

This study is embedded and conducted within the research project STEM@School. 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. One teacher taught mathematics, physics and (integrated) STEM and one teacher taught both mathematics and physics.

### *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.

### *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.

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

### Teacher's **Structure**

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

### Teacher's **Involvement**

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

### Students Collective **Engagement**

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

<u>Note for Each Rating</u>: 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 |

### *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.

## 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. *$p< .05$. **$p<.01$. ***$p<.001$.

## *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 ($\beta = .26$, $p<.05$), while autonomy support negatively predicted autonomous motivation ($\beta = -.22$, $p<.05$). 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. *$p<.05$. **$p<.01$. ***$p<.001$.

### *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.

### *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.

## 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.

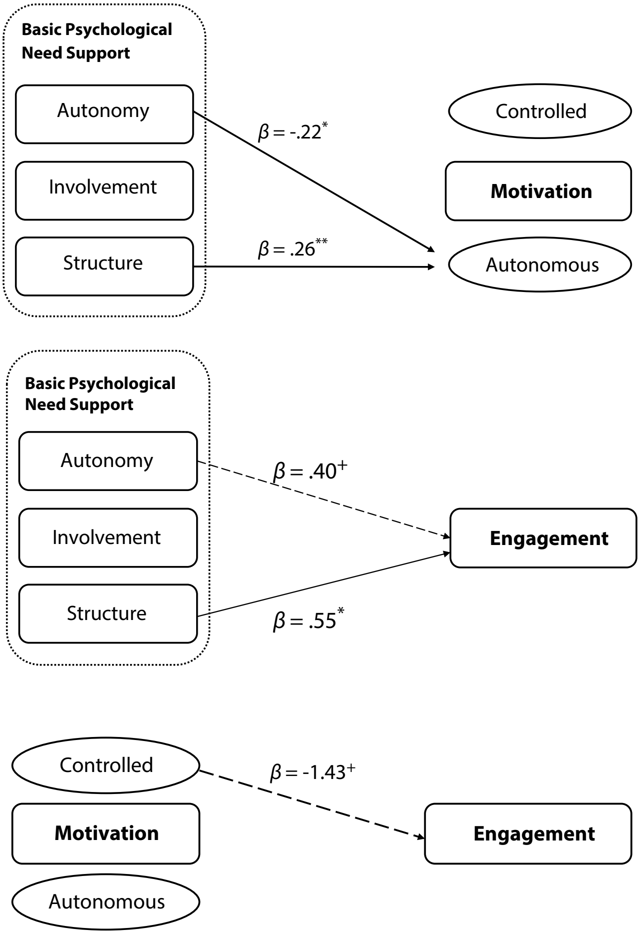



**Figure 4.** Summary of results: link between basic psychological need support, students' motivation and engagement.

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).

### *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.

### *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.

### *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 self-reports), 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).

### *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).

### *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.

## 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.

# CHAPTER 4

# Study 3:

## Students' engagement in different STEM learning environments: Integrated STEM education as promising practice?[6]

6 This chapter is based on: Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: Integrated STEM education as promising practice? *International Journal of Science Education*, DOI: 10.1080/09500693.2019.1607983

## Abstract

In this paper, we explore how students' engagement varies in different STEM (Science, Technology, engineering, Mathematics) learning environments. More specifically, we focus on the significance of a learning environment applying an integrated STEM (iSTEM) approach and the significance of STEM learning environments' student-centredness. Moreover, we explore the relative importance of different student-centred principles (lesson plan and implementation, communicative interactions, student-teacher relationships) for students' engagement in the STEM learning environment. Applying a mixed-method approach, we draw from observational data of 24 STEM lessons in combination with data from seven focus groups with 67 grade 9 students. The quantitative findings, based on the observational data, show that a learning environment applying an iSTEM approach seems to support students' engagement. Further investigation made it clear that the student-centredness in this learning environment is especially significant. Regarding the specific student-centred principles, all principles had a significant impact on students' engagement. The focus group data make clear that, besides student-centredness, the integrative aspect and the use of authentic real-world problems in iSTEM can also be engaging for students. These results indicate that iSTEM is a good practice to engage students in the STEM learning environment, as it facilitates teachers' implementation of a general student-centred approach.

## Introduction

Policymakers and educational researchers worldwide, increasingly focus on ensuring students' persistence and success in Science, Technology, Engineering and Mathematics (STEM) (Skinner, Saxton, Currie, & Shusterman, 2017) and students' preparation for the labour market in which STEM takes a prominent place (World Economic Forum [WEF], 2017). Compulsory education plays a central role in achieving this goal. However, according to the World Economic Forum (2017), many education systems today prepare students insufficiently for the labour market as they are based on educational models introduced over a century ago. For instance, most STEM education in primary and secondary schools focuses on theory rather than on application and experiential learning and is taught in a way that reinforces a disconnect between the different STEM disciplines (Nadelson & Seifert, 2017; WEF, 2017).

In order to attract a larger number of students who are more engaged in STEM and provide them with essential 21st century skills such as complex problem-solving and teamwork (see e.g. Salonen, Hartikainen-Ahia, Hense, Scheersoi, & Keinonen, 2017; Struyf, Boeve-de Pauw, & Van Petegem, 2017), a shift towards more student-centred learning environments is generally assumed to be needed (Gasiewski, Eagan, Garcia, Hurtado & Chang, 2012; Sawada et al., 2002). A student-centred learning environment provides students with opportunities to take a more active role in their own learning, rather than being passive receivers of information (Anderson, 2007; Brush & Saye, 2000). Students need to analyse and synthesise the learning content themselves through e.g. examining complex problems, using a variety of means and developing their own strategies to solve these problems in a collaborative manner (Brush & Saye, 2000).

Within this shift towards more student-centred learning environments, the current international focus in STEM education includes a movement towards integrating the separate STEM disciplines in the curriculum through 'integrated STEM' (iSTEM) (Honey, Pearson, & Schweingruber, 2014; Koul, Fraser, Maynard, & Tade, 2017; Moore & Smith, 2014; Nadelson & Seifert, 2017; Sanders, 2009). 'iSTEM' can generally be defined as 'the seamless amalgamation of content and concepts from multiple STEM disciplines. The integration takes place in ways such that knowledge and process of the specific STEM disciplines are considered simultaneously, without regard to the discipline, but rather in the context of a problem, project or task' (Nadelson & Seifert, 2017, p. 221). In contrast to traditional 'segregated' STEM, integrated STEM requires the application of knowledge and practices from various STEM disciplines to solve complex and transdisciplinary problems (Nadelson & Seifert, 2017).

As engaging students in STEM is an urgent need in society, it is important to investigate which learning environments can foster and promote pupils' engagement towards STEM (Skinner et al., 2017).

Using a mixed method approach, we draw in this research from observational data of diverse STEM lessons in combination with data from focus groups with grade 9 students. The observations include lessons of segregated domain-specific STEM disciplines and iSTEM lessons. Through quantitative analysis of the observational data, we examine how student engagement varies in different STEM learning environments. More specifically, we investigate the significance of an iSTEM approach and the STEM learning environment student-centredness for students' engagement. Furthermore, we explore the relative importance of different student-centred principles in terms of engaging students. Focus group data enrich these findings with the narrative experiences of students.

### *Students' engagement*

In this study, we conceptualise engagement as 'the behavioural intensity and emotional quality of a person's active involvement during a task' (Reeve, Jang, Carrell, Jeon, & Barch, 2004, p. 147). The behavioural dimension of students' engagement consists of effort, attention and persistence during learning activities. The emotional dimension of engagement includes students' emotional involvement during learning activities, such as enthusiasm, interest and enjoyment (Reeve et al., 2004; Skinner, Furrer, Marchand & Kindermann, 2008). In contrast to engagement, disengagement or *disaffection* is evident in students who are passive, discouraged and give up easily (Skinner et al., 2008; Skinner et al., 2017). Engagement is an important educational construct as it causes many positive student outcomes such as academic learning, achievement, skill development, and academic resilience in different educational fields, (Reeve, 2012; Skinner et al., 2008) including the STEM educational field (Bathgate & Schunn, 2017; Skinner et al., 2017). Engagement can be approached and measured differently based on the 'grain size' of the context. This can range from an individual level, such as a person's individual engagement during a task, to a macro level. The latter refers to the engagement of a group of learners in a class, course, school or community (Sinatra, Heddy, & Lombardi, 2015). In the current study, we conceptualise and measure students' *collective* engagement in the classroom.

### *Student-centred learning environments*

Student-centred learning environments are inspired by the constructivist learning theory, which has gained much attention in educational research over the past few decades (Baeten, Dochy, & Struyven, 2012). The ideology behind this theory is that learning is an active process of knowledge construction in which learners construct meaning for themselves, based on prior constructions. While some educational researchers argue that active knowledge construction can take place regardless of the teaching method or type of learning environment, others highlight the need to create constructivist learning environments which are typically student-centred (Anderson, 2007; Baeten et al., 2012). Other labels, besides 'student-centred' that can be found in the literature and refer to constructivist teaching methods (Baeten et al., 2012) are, for example, 'inquiry-based' (Anderson, 2007; Loyens & Rikers, 2011) or 'student-activating' (Baeten et al., 2012; Struyven, Dochy, & Janssens, 2008).

Sawada et al. (2002) defined several overarching student-centred principles, based on a review of the literature, that allow researchers to measure the degree to which a learning environment is student-centred. These principles; lesson plan and implementation, communicative interactions and student-teacher relationships will be discussed. Typically, both teachers and students take on a different role in a student-centred learning environment, in contrast to a traditional teacher-centred or 'lecture based' learning environment, resulting in different *student-teacher relationships* (Anderson, 2007; Brush & Saye, 2000). The teacher's role transforms to that of a coach and facilitator instead of a dispenser of knowledge. (S)he encourages students' active participation through 'hands-on' and 'minds-on' activities. Moreover, the teacher's role is to stimulate students to find more than one solution for a problem (Sawada et al., 2000). (S)he walks around, listens to students and helps students to process information, communicates with student groups and models the learning process (Anderson, 2007). Students, meanwhile, become self-directed learners instead of passive receivers of information. Students focus on processing information instead of recording it and interpret and explain information rather than solely memorising it (Anderson, 2007; Schmid & Bogner, 2017). Additionally, the type of student work changes. For instance, students need to direct their own work to a larger extent; tasks vary among students and often include solving and explaining complex problems (Anderson, 2007). *Communicative interactions* taking place in a student-centred classroom are consequently more diverse and decentralised (Sawada et al., 2002). In contrast to a traditional learning environment, the teacher is not the centre of attention during the lesson. Students communicate with the teacher and with each other by, for instance, brainstorming, critiquing or group work (Anderson, 2007; Sawada et al., 2000). Moreover, the *lesson plan and implementation* in a student-centred learning environment is organised in a manner that the ideas that students bring to the classroom are acknowledged and respected. Students are considered as a community of inquirers (Sawada et al., 2002).

Previous studies investigating the link between student-centred STEM learning environments and students' engagement found mostly positive to mixed results. In a study, Wu and Huang (2007) found that students in a student-centred technology-enhanced STEM learning environment reported higher levels of emotional engagement, compared to students in a teacher-centred learning environment. But, when comparing different student groups, low-achieving students in the student-centred learning environment demonstrated more disengagement and engaged in fewer conceptual discussions, while they achieved better in a teacher-centred STEM learning environment. Research by Hampden-Thompson & Bennett (2013) examined the variance in students' reports of engagement in science across science teaching and learning activities. Higher levels of students' emotional engagement towards science were found in classrooms where students reported higher levels of interaction, hands-on activities and applications in science. Gasiewski et al. (2012) investigated the relationship between students' engagement and introductory STEM courses and found that students were more emotionally and behaviourally engaged in STEM classrooms where professors applied a student-centred approach and where collaboration with others frequently took place. More research in diverse contexts, using a number of different research methods, is needed to gain more insight into how different STEM learning environments can play a role in promoting students' engagement.

### *The iSTEM approach as a student-centred STEM learning environment*

STEM can be placed on a continuum, with segregated domain-specific STEM at one end (e.g. separated mathematics, physics) and integrated domain-general STEM (iSTEM) at the other end of the continuum (Nadelson & Seifert, 2017). Complex research problems occurring in today's industry and society mostly need the use of iSTEM (Nadelson & Seifert, 2017; Wang, Moore, Roehrig, & Park, 2011), while, in contrast, most STEM education in primary and secondary education is more aligned to segregated domain-specific STEM (Nadelson & Seifert, 2017). At the same time, there is a pedagogical shift in favour of integrating the four disciplines of STEM at school level into one class or a unit, based on the connections among the disciplines and real-world problems (Moore & Smith, 2014).

As problems requiring an iSTEM approach are typically ill-structured with multiple solutions, iSTEM education requires a student-centred learning environment (Moore & Smith, 2014; Nadelson & Seifert, 2017). Based on a review of existing literature identifying multiple characteristics of iSTEM education, Thibaut et al. (2018a) discerned five specific key principles that are used for iSTEM education and can guide the design of an iSTEM approach in secondary education.

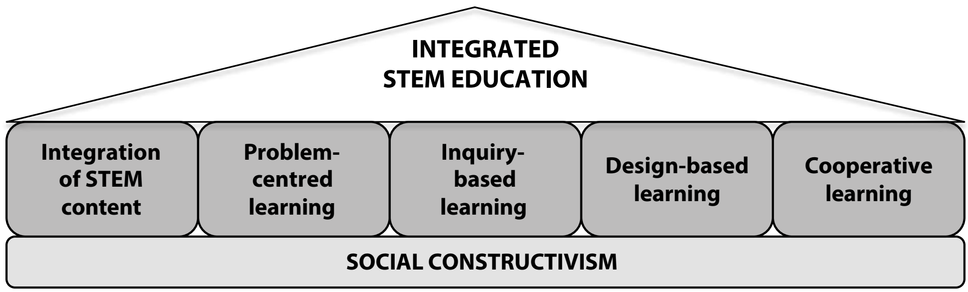



**Figure 1.** Theoretical framework for integrated STEM education (Thibaut et al., 2018a)

The first key principle is *the integration of STEM content*, which entails purposefully integrating content from various STEM disciplines. Secondly, *problem-centred learning* indicates the use of authentic real-world problems to increase the relevance of the learning content. Third, *inquiry-based learning*, in this context, refers to engaging students in questioning, experiential learning and hands-on activities that allow them to discover new concepts and develop new understandings. The fourth key principle, *design-based learning*, refers to learning environments that engage students in technological or engineering design. The final principle, *cooperative learning*, relates to the promotion of teamwork and collaboration with others through the use of, for example, small learning groups. In contrast to the instructional practice of 'collaborative learning', 'cooperative learning' emphasises teachers' guidance (Thibaut et al., 2018a). In the latter, the teacher moves from one student group to the other, observes and intervenes when necessary. In the case of collaborative learning, the teacher will not actively monitor the different student groups and will refer all substantive questions back to the group to resolve (Matthews, 1995; Thibaut et al., 2018a).

Obviously, there are some overarching aspects that relate these key principles to each other. All key principles, for instance, are supported by a constructivist view on learning (Thibaut et al., 2018a). Thus, it is not surprising that the last four key principles (problem-centred learning, design-based learning, inquiry-based learning and collaborative learning) are student-centred teaching methods. Students need to take an active role in their learning and the teachers should become a guide on the sideline Moreover, these last principles all promote the development of 21st century skills, such as problem solving, critical thinking, creative and innovative thinking and collaboration and teamwork skills (Binkley et al., 2012; Thibaut et al., 2018a).

Regarding the effect of iSTEM education on students' cognitive and affective outcomes, several empirical studies have found a positive impact. It has been found to improve students' achievement (Austin, Hirstein, & Walen, 1997; Hurley, 2001), interest in STEM (Mustafa, Ismail, Tasir, Said & Haruzuan, 2016; Riskowski, Todd, Wee, Dark & Harbor, 2009), motivation to learn (Gutherie, Wigfield, & VonSecker, 2000; Stohlmann, Moore, & Roehrig, 2012) and career interest in STEM (Koul et al., 2017). To our knowledge, no study has investigated the effect of iSTEM education on students' engagement. However, Skinner et al. (2017, p. 2437) argue that students' engagement in STEM could be promoted by interesting authentic academic work which they define as work that is 'hands-on, heads-on, experiential, project-based, authentic, relevant, progressive and integrated across subject matter'.

## Aim of the present study

The aim of this study is to investigate how grade 9 students' engagement occurs in different STEM learning environments. We examine which of these STEM learning environments supports students' engagement, with a specific focus on a learning environment applying the iSTEM approach and the STEM learning environment's student-centredness. Furthermore, we investigate the relative importance of different student-centred principles in terms of facilitating students' collective engagement. We assume that the iSTEM approach is in reality not always implemented in a highly student-centred manner. On the other hand, domain-specific STEM might include a high degree of student-centredness. Therefore, we choose to split up both concepts theoretically: (a) iSTEM versus domain specific STEM and (b) degree of student-centredness (see Figure 2). Specifically, we aim to answer the following research questions (RQs):

RQ1: To what extent does (a) an iSTEM approach and (b) the degree of student-centredness in the STEM learning environment support grade 9 students' collective engagement?

RQ2: To what extent do the different student-centred principles support grade 9 students' collective engagement in the STEM learning environment?

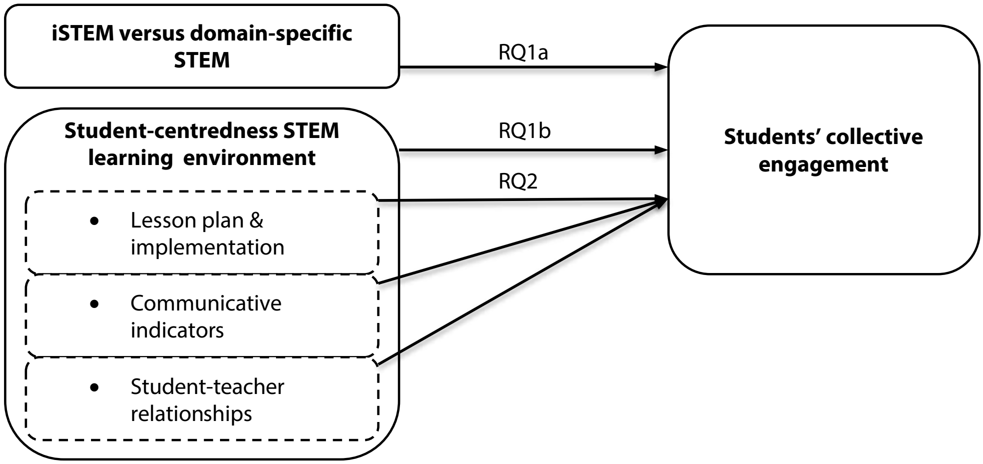



**Figure 2.** Visualised scheme of research questions in this study

## Methodology

### *Research context, procedure and participants*

We conducted our study within the STEM@School research and development project. The overall aim of this project is to increase students' achievement, motivation and engagement with regard to STEM. Within this project, a team of other researchers with a professional background in STEM developed iSTEM learning modules for students in secondary education. For 9th graders, three different modules were developed. In the first module, students were challenged to design and build an autonomous driving car that could drive through a 'green wave'. In the second module students had to design and build a museum security system and, in the last module, a rehabilitation device. The five key principles of iSTEM education provide a well-defined framework for instructional practices in iSTEM in secondary education and guided the design of the three modules.

In order to provide a rich understanding of students' engagement with regard to different STEM learning environments, we applied a mixed method approach. Observations were chosen to provide a general picture of how different STEM learning environments relate to students' engagement. Focus groups were chosen as complementary methodology to enrich the observational data through students' narrative experiences. Thus, we aimed to explore in more detail, through the qualitative focus group data, how students' engagement manifests itself within these different STEM learning environments.

We conducted observations between January and May 2016, during the implementation of the last two STEM@School modules. For the observations during the second module, we randomly selected nine schools among the 41 Flemish schools that participated in the project. From each of these schools we selected one 9th grade class to participate in this study. In each of these classes, we selected one mathematics lesson, one physics lesson and, when included in the curriculum, one iSTEM lesson for observation. We videotaped each observation and after screening the visual and auditory quality of the observational data, 18 observations remained, including eight mathematics lessons, five physics lessons and five iSTEM lessons. To provide extra observational data, we videotaped six extra iSTEM lessons during the third module, in six other randomly selected schools participating in the project. Each observed lesson lasted between 50 and 100 minutes.

All selected classes for the observations followed a curriculum with a general focus on STEM (note: not necessarily iSTEM). However, 12 of them had a curriculum that focused on science and mathematics, while the other three classes had a particular focus on technology and engineering. Moreover, two of those classes followed a traditional curriculum without the iSTEM course. In all the other classes, the iSTEM course was included in the curriculum. Approximately 10% of the curriculum was devoted to the iSTEM course in these classes. In total 321 $9^{th}$ grade students attended the observed lessons (68% male, 32% female, age: $M = 14.54$; $SD = .88$).

On the same day of the observation(s) in the second module, we held focus groups with randomly selected students from these observed classes. Altogether, 67 respondents, of whom 42 were male, participated. The group size ranged from 7 to 12 students, which is an appropriate group size for a focus group (Osborne & Collins, 2001). Each focus group had a duration of approximately one hour and was audio recorded. In line with Belgian legislation, we obtained permission from the students and their parents to participate in the observations, using a passive informed consent procedure. For the focus groups, we obtained an active informed consent from the participating students.

### *Observations*

*Measures and variables*

To measure *students' engagement* we used a subscale of the observation instrument of Reeve et al. (2004), measuring students' collective classroom engagement. This scale includes both behavioural and emotional engagement. Each item is placed on a continuum ranging from 1 to 7 with bipolar descriptors of students' (dis)engagement. Items and the reliability of the scale can be found in Table 1. The first two authors of this study rated all videotaped observations on students' engagement independently to avoid social influence bias. The interrater reliability, based on the correlation coefficients, was satisfactory (*IRR*= .80). Based on the video recordings, the researchers considered both the frequency and intensity of the students' behaviour and emotions during the rating procedure. A high score for students' engagement was given when most or almost all the students in the classroom were behaviourally and emotionally engaged. Average engagement scores in the observed lessons varied from a score of 2.1 to 6.8. The researchers explicitly discussed each score they gave for the first five rated observations, in order to ensure that they were interpreting the various items in the same way. When there was a different interpretation of an item, scores were justified after agreement was reached. When a conflict in scores occurred after rating the remaining observations, scores were not modified.

The learning environment's *student-centredness* was observed with the Reformed Teaching Observation Protocol (RTOP) (Sawada et al., 2002). We took two of the three scales into account: *Lesson Design and Implementation* and *Classroom Culture.* The first scale focuses on measuring to what extent ideas brought to the classroom by pupils were acknowledged and respected. The latter includes the diversity of communicative interactions and student-teacher relationships, including the degree of teacher support towards the initiatives coming from the pupils (Sawada et al., 2002). Table 1 shows the reliability of the different scales and all the items included. After carefully going through the RTOP training guide (Sawada et al., 2000), the two observers discussed all the items to guarantee that they were interpreted in the same way. As a next step, they rated the items on a scale from 0 (not observed) to 4 (very descriptive). Higher scores reflected a higher degree of the learning environment's student-centeredness (Sawada et al., 2000). This rating procedure was performed approximately six months after rating students' engagement. Both researchers rated the first five observations independently and the interrater reliability was satisfactory (*IRR* = .88).

**Table 1.** Variables in this study and reliability coefficients

| | C. α |
|---|---|
| **Dependent variable** | |
| **Collective classroom engagement** | **0.94** |
| 'Dispersed' versus 'focused attention' | |
| 'Passive, slow, minimal effort' versus 'active, quick, intense effort' | |
| 'Verbally silent' versus 'verbally participating' | |
| During challenge, failure or confusion: 'students give up easily' versus 'persist' | |
| 'Flat' versus 'positive emotional tone' | |
| **Independent variables** | |
| **Lesson plan & implementation** | **0.83** |
| Instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein | |
| The lesson was designed to engage students as members of a learning community. | |
| Student exploration preceded formal presentation | |
| Students were encouraged to seek and value alternative methods of investigation or of problem solving | |
| The focus and direction of the lesson was often determined by ideas originating from the students. | |
| **Communicative interactions** | **0.79** |
| Students were involved in the communication of their ideas to others using a variety of means and media. | |
| The teachers' questions triggered divergent modes of thinking. | |
| There was a high proportion of student talk and a significant amount of it occurred between and among students. | |
| Student questions and comments often determined the focus and direction of classroom discourse. | |
| There was a climate of respect for what others had to say. | |
| **Student- teacher relationships** | **0.82** |
| Active participation of students was encouraged and valued. | |
| Students were encouraged to generate conjectures, alternative solution strategies and ways of interpreting evidence. | |
| In general the teacher was patient with students. | |
| The teacher acted as a resource person, working to support and enhance student investigations. | |
| The metaphor 'teacher as listener' was very characteristic of this classroom. | |

*Quantitative analysis*

Considering that students' engagement could differ across different class groups, regardless of the iSTEM approach and the STEM learning environment's student-centredness, we took into account the class group as a variable in order to answer RQ1. We performed multilevel analyses using JMP (John's Macintosh Project) version pro 13. First, we performed multilevel analysis, exploring the significance of the iSTEM approach for students' engagement, including the class group as a random effect (Model I). Note that only one class group was included per school, which implies that no separate level for the school was included in the model. Second, we added the total student-centredness of the STEM learning environment to the first model, which resulted in Model II. In order to understand which student-centred principles could predict students' engagement (RQ2), we performed additional multilevel analyses taking the three different subscales into account instead of the overarching student-centredness variable. However, due to insufficient power (the mean power of the three scales was 0,49), we were not able to investigate the predictive value, taking the three different scales together in one model. As an alternative approach, we built three different models, with the separate scales, to predict engagement while still taking the random effect of the school into account (Models IIIa, IIIb, IIIc). To examine agreement among class groups, we computed intra-cluster correlation coefficients (ICC) (e.g. Mouratidis, Vansteenkiste, Sideridis, & Lens, 2011).

### *Focus groups*

For the focus groups, we developed a semi-structured interview guide including questions regarding students' perceptions of the STEM learning environment and their experiences with it. At the start of the focus group we explained the focus group's aim, the confidentiality of the data and some general focus group rules. As an icebreaker, students could present themselves by sharing the reason for their current study choice and their career aspirations. Next, students were asked to write down a description of a typical physics, mathematics and, if applicable, iSTEM lesson. Specific focus was given to the teacher's role, the students' roles and student work. After this, students were asked to discuss with the other respondents what they had written down and share their positive and negative experiences about the learning environment. More specific questions were provided and related to students' perceptions and experiences about the amount of group work and discussions during the lessons, the relevance of the lesson and what the teacher would do if pupils were stuck when trying to solve an exercise. At the end of the focus group, students could also indicate what they would change about the learning environment.

In Table 2, an overview of the focus groups can be found, accompanied by a description of the collective engagement level in each observed lesson that respondents in the focus group attended. We categorised students' engagement level as; 'high' if the scores of students' observed engagement ranged between 5 and 7, 'average' with scores between 3 and 4.9 and 'low' with scores between 0 and 2.9. For focus groups, where no description of the engagement level in iSTEM can be found in Table 2, there was no iSTEM lesson included in the STEM learning environment.

**Table 2.** Overview of focus groups and students' observed engagement in the STEM learning environment

| | Students' collective engagement level | | |
|---|---|---|---|
| **Focus group (FG)** | **iSTEM** | **Physics** | **Mathematics** |
| **FG1** | high | Average | High |
| **FG2** | - | High | Average |
| **FG3** | high | High | Low |
| **FG4** | average | - | High |
| **FG5** | average | - | - |
| **FG6** | high | - | Average |
| **FG7** | - | Low | Average |

*Qualitative analysis*

We analysed the focus groups, using thematic analysis (Braun & Clarke, 2006). First, the focus groups were transcribed and the process of (re)reading began to enable familiarity with the data. Notes of initial thoughts and reflections aroused by fragments in the transcript were simultaneously taken. The qualitative data analysis software Nvivo 10 supported the next steps in the analysis process. We generated initial codes across the whole data set and thereafter, gathered these under broader codes. Coding during this step of the analysis was theory-driven. Based on students' expressions of emotions and behaviour, we categorised students' narratives using the motivational conceptualisation of engagement and disaffection in the classroom of Skinner et al. (2008). The latter provides a fine-grained categorisation of students' emotions and behaviours. Students' descriptions of the STEM learning environment were categorised under the five key principles of iSTEM (Thibaut et al., 2018a) and the student-centred principles included in the RTOP (Sawada et al., 2000). The fourth step consisted of reviewing the themes in relation to the coded fragments and the whole data set, with a thematic map of analysis as a result. Fifth, we refined the specifics of each theme and divided certain themes into smaller sub-themes. Finally, we selected and further analysed vivid quotes from the students in the focus group, relating back to the research questions and the literature (Braun & Clarke, 2006). In order to protect the respondents' privacy, only pseudonyms are reported in this paper.

## Results

First we discuss the results regarding the significance of the iSTEM approach and the STEM learning environment's student-centredness for students' collective engagement. Next, we report the results about the significance of the three student-centred principles (lesson plan and implementation, communicative interactions, student-teacher relationships) in this regard.

### *Students' engagement in different STEM learning environments*

The results reveal that the iSTEM approach was not significant. However, we should be cautious about accepting the null hypothesis (Pritschet, Powell, & Horne, 2016), as the iSTEM approach was marginally significant [F (1, 21.7)]= 3.01, p = 0.09 (Model I). Students' average engagement in a STEM learning environment with an iSTEM approach was 5.10, while students' engagement in a learning environment with 'domain-specific' STEM was 4.19. When we added the learning environment's total student-centredness to the model (Model Π), the latter was significant [F (1, 21)]= 8.29, $p < .01$ for students' engagement and it decreased the amount of explained variance of a learning environment with or without the iSTEM approach (see Table 3). Approximately 41% of the variation in students' engagement was a function of the class group (ICC= 0.41).

**Table 3.** Relationship between the type of STEM learning environment and students' engagement

| | Models | |
|---|---|---|
| | I | Π |
| β iSTEM versus domain-specific STEM | .71⁺ | .06 |
| β Student-centredness | | .61** |

Note: ⁺*p*<.10 **p*<.05. ***p*<.01. ****p*<.001.

The focus group data make these findings more clear, in the sense that, when students in the focus groups expressed that they were emotionally and behaviourally engaged towards iSTEM, this was mostly associated with the student-centredness within this learning environment. For example, designing, collaborating with others and experiencing 'freedom' in these lessons, were mentioned by respondents as engaging aspects. As the next quotes illustrate, respondents in FG1 and FG4 clearly stated that they felt that the iSTEM lessons were generally more student-centred compared to teacher-centred learning environments, which in turn was associated with more expressed engagement.

Melanie: During working [in iSTEM lesson] she [teacher] comes to look around to see if we are doing it well.
Interviewer: What happens when you are stuck in a hard exercise?
Melanie Then we raise our hand and she helps us a little bit further, so we can go on. She doesn't tell us everything.
(….)
Bob: During physics she [same teacher] is just constantly talking and we just have to pay attention.
Nick: There is a more boring atmosphere in physics, in contrast to iSTEM; it's a lot more fun there.
Bob: In iSTEM we are really busy, for example, with that little car. In contrast to physics, there you really have to just sit and listen.
(FG4)

The following quote illustrates that, besides a generally student-centred approach in iSTEM, also the integration of STEM content can support students' engagement, if the direct relevance of the subject matter becomes clearer through the integration and application.

Michael: I find it good [iSTEM] because you can often cooperate and because it often involves projects. You do learn from just opening a book, but I find that a very boring manner of learning. I wrote it all down now and I understand it, but what will I actually get out of it? You have this less with iSTEM, because you really learn how helpful it is for you. You see that you can calculate this and it is handy for that. Then you get a better image of it and you benefit more from it, in my opinion.
Interviewer: So, you mean that you understand more why you need to know it?
Michael: Yes, indeed. For physics, they teach us for example hydrostatic pressure. Then you know that there is so much pressure on water, but what will I get out of it?
Interviewer: Can you give an example of the iSTEM lesson that made you to understand the use?
Michael: For example, programming this little car. You know how to calculate the velocity and then you can perfectly adapt it. With the formula of velocity as such … ok you know it, but then you don't have a very good image of it yet.
(FG1)

The data indicate that also the use of authentic real-world problems, through problem-centred learning, can positively influence students' engagement. Nevertheless, this was more the case when students experienced this problem as personally relevant and closely related to problems in the 'real world'. The next quotes from FG4 and FG6 clarify this:

Nick I think I will practise a STEM profession, because I like it. For example, this car we had to make and try out. I liked it and later on you can also really make and develop it, to then later improve it and update it.
(FG4)

Sam: That's actually why I chose STEM [iSTEM], because you can work on this museum security system. But this car, we will never use it later on, but after all it's nice to know.
Tom: But sometimes it could be more comprehensive. For example, in this museum security system we only work with lasers. In a real museum security system they will do much more.

(FG6)

### *Student-centred principles and students' engagement*

Multilevel analysis shows that the scale 'lesson plan & implementation' was not significant at the .05 level, but marginally significant for students' collective engagement [F (1, 20.7)]= 3.73, $p$ = 0.07 (Model IIIa). 'Communicative interactions' (Model IIIb) and 'student/teacher relationships' (Model IIIc) were both significant; [F (1, 20.5)]= 9.44, $p < .01$ and [F (1, 19.3)]= 11.3, $p < .01$. More details can be found in Table 4. The ICC in Models IIIa and IIIb was equal to 0.41, which means that 41% of the variation in students' engagement was a function of the class group. In Model IIIc the ICC was equal to 0.39. How students' engagement manifests itself in relation to the various student-centred principles will be discussed below in more detail, illustrated by students' narrative experiences.

**Table 4.** Relationship between student-centred principles and students' engagement

| | Models | | |
|---|---|---|---|
| | IΠa | IΠb | IΠc |
| β iSTEM versus domain-specific STEM | .24 | .02 | .16 |
| β Lesson plan & implementation | $.44^{+}$ | | |
| β Communicative interactions | | .64** | |
| β Student-teacher relationships | | | .64** |

Note: $^{+}p<.10$ *$p<.05$. **$p<.01$. ***$p<.001$.

### *Lesson plan and implementation*

The quantitative results showed that 'lesson plan and implementation' was marginally significant for students' collective engagement. The results of the focus groups demonstrate in more detail how 'lesson plan and implementation' in the STEM learning environment can promote or thwart students' engagement. Many respondents appreciated and indicated that they were emotionally engaged when the class group would be considered as a learning community. In FG1, for example, students were highly engaged for STEM and mathematics, but indicated that they missed group discussions about the subject matter. While students would enjoy it if the teacher would actively appeal for students' knowledge and ideas, the teacher would instead directly answer students' questions. Hence, the teacher did not value alternative modes of investigation or problem solving. This led to frustration for students who were initially intrinsically interested and highly engaged.

| | |
|---|---|
| Jonas: | It's a pity that madam [iSTEM and physics teacher] is never open to discussions, also not about the content of the lesson. Although we did this the last two years and I found it pleasant and you also learn from it. Now madam avoids this directly. |
| Interviewer: | So you have never had group discussions? |
| Jonas: | No, never! |
| Interviewer: | What would you like to discuss? |
| Jonas: | Really everything. |
| Interviewer: | About which specific subject matter for example? |
| Jonas: | Sometimes if you interpreted something differently, that you, for example, heard from another teacher; 'the sun is yellow because there is pigment in it'. But then Madam says: 'oh no, the sun is yellow because it is a plasma ball'. |
| Michael: | Maybe this is something for the professionalisation of STEM-teachers, learning to be open to discussions (laughs) |

(FG1)

In FG5, students showed interest in sharing knowledge with other pupils, like in a real learning community, when they were asked what they would change about the iSTEM lessons. Mostly they worked alone or in twos, but they saw it as an advantage to make an appeal to each pupil's knowledge to find a faster solution for complex problems.

| | |
|---|---|
| Sarah: | I would involve the class more. Because now we are working mostly in twos, but if these two people don't get along well and such... I would work with more people at the same time, because if you both don't understand it. |
| Interviewer: | You would work with the whole class group? |
| Sarah: | With more people and negotiate more, because together we mostly get to a very good answer, but we don't do it enough. Everyone has ideas. Everyone paid attention to different aspects and together we would have finally figured out a strategy. |

(FG5)

The focus group data reveal that not only the fact that students are considered as a learning community can be important for students' engagement, but also the fact that the focus and direction of the lesson is consequently regularly determined by ideas originating from the students. An example that occurred during one of the observations in an iSTEM lesson, worded by students in FG6, illustrates this finding well. Respondents in this focus group explained that their iSTEM teacher organised a brainstorm to apply students' ideas regarding the appropriate material for designing a light box. However, the teacher finally imposed the material, which made the students feel disappointed and emotionally disengaged. At the same time, they shared their enthusiasm for design activities about which they had more control.

| | |
|---|---|
| Ella: | Mostly you don't get anything out of it [brainstorm/ group discussion]. |
| Tom: | Finally you know that it will become sir's [iSTEM teacher] decision! I said 'no paper' for the light box and then finally it became a carton. |
| Interviewer: | So finally you don't decide how it really becomes? |
| Tom: | Mostly not. The previous semester it was allowed more. Then you had to program and you could choose what to program. If you had got the basics, you could attach sirens and so on. You could choose yourself what to do. That was fun. Now, in contrast, you can't really experiment yourself. It's just 'do that'. |

(FG6)

In a few focus groups students also expressed interest and enthusiasm about choosing the topic of a project, based on the interests of the class group.

### *Communicative interactions*

Multilevel analysis showed that communicative interactions were significant for students' collective engagement. Also the qualitative data illustrate the importance of this scale. Students' engagement level in FG3 was categorised as 'low' for physics, which was an exceptional engagement level across the observational data. When students in this focus group described how their physics lessons mostly occurred, they described this as a very teacher-centred learning environment. The teacher would give his Power Point presentation and students only had to listen. Thus, there was nearly no student talk occurring between and among students. Additionally, they stated that the teacher would not always answer students' questions or remarks, which indicated that the student-centred principle 'there was a climate of respect for what others had to say' was also not applicable in these lessons. Obviously, students mentioned that they were both emotionally and behaviourally disengaged in this learning environment and suggested that they would appreciate more 'action' in the classroom.

| | |
|---|---|
| Matthias: | I find physics and chemistry – we get it from the same teacher – really boring. I know I speak for all, if I am saying this. |
| Interviewer: | How do these lessons mostly go? |
| Matthias: | The teacher stands in front, we sit and he is just teaching, continuously talking without a pause. Then it is just your course, everything is filled in so you don't have to do anything. We look at the blackboard, but yes it is quite hard to pay attention. |
| Interviewer: | Do the others feel the same about it? |
| John: | Me a bit less, but it depends on what it is about, of course, because some things are more interesting for someone else than for the other. It would be nicer if we could fill in the course a bit ourselves. Then we would catch up faster. |

(FG7)

The focus group data illustrate that the student-centred principle 'students were involved in the communication of their ideas to others using a variety of means and media' was also of importance for students' engagement. Most respondents found group work, critiquing or brainstorming engaging activities. Most students valued group work because they found it beneficial to find solutions together or to ask other pupils help in understanding the subject matter.

### *Student-teacher relationships*

The quantitative data revealed that student-teacher relationships were significant for students' collective engagement. Importantly, the qualitative data reveal that it is not only important that the teacher acts as a resource person not telling students what to do and how to do it, but also that students experience enough help. In FG5, students shared their experience about a programming lesson. They stated that they simply had to follow directions, while most students actually did not understand the subject matter. Thus, they were 'active' but not actively thinking and making decisions. On the other hand they experienced a lack of help due to the teacher's high expectations of the STEM class. Those experiences made those students feel frustrated and overwhelmed.

| | |
|---|---|
| Amélie: | They [iSTEM teachers] just can't explain it. They both can do it well, but they are not used to explaining it all to the letter to us, because we all don't understand it very well yet. Programming was hell. |
| Charlotte: | They just said 'go ahead'. |
| Amélie: | Yes, programming was just retyping. There was an example and we just had to adjust some small things and further just retype. |
| Charlotte: | (…) |
| Kim: | In the 12th grade they have to take the matters in their own hands, but we've just come from the 8th grade where they hold our hand the whole time. We have never had any lessons about it. |
| Amélie: | All these teachers think that we are amazingly clever.<br>Then they say 'I expected more of a STEM-class'. I find that horrible. |

(FG5)

In contrast to the experiences of these students, students in FG6, who had a high engagement level in the iSTEM lesson, felt more guided by the iSTEM teacher as he was giving, in their opinion, sufficient hints and regularly made an exercise together with the whole class. This was clearly appreciated by the respondents. The fact that the teacher was giving hints, also indicates that the teacher would actively listen to what students were saying and that he showed patience. The quote below does not only illustrate that the teacher was a 'guide on the side', but that he also considered his class as a learning community where everyone could talk about their ideas.

| | |
|---|---|
| Interviewer: | What happens when you are stuck solving a hard task during the lesson [iSTEM]? |
| Thomas: | Then we mostly say it all. The whole group participates and everyone talks about their ideas. |
| Emma: | Or we ask Sir [iSTEM teacher] and then he helps us, but he never helps us too much. We have to keep finding solutions ourselves. |
| Aurélie: | Then he shows us a part of it. |
| Thomas: | Or we look on the internet or in the course. |
| Interviewer: | You say he always shows a part of how to do it? |
| Aurélie: | Yes, certain things, if it is really too hard, but he never tells us the solution directly. |
| Emma: | He gives hints. |
| Aurélie: | But we will also never have to make an exercise about something we have never made exercises about before. He always shows a few, so that's good. |

(FG6)

## Discussion

The aim of this study was to investigate how students' engagement occurs in different STEM learning environments by applying a mixed-method approach. As engaging students in STEM is an important need in society, research in diverse contexts, making use of different research methods is needed in order to understand how students' engagement in STEM can be promoted. In this study we focused on how a learning environment applying an iSTEM approach and STEM learning environments' student-centredness can play a role in promoting grade 9 students' collective classroom engagement. Furthermore, we investigated which student-centred principles were most significant and meaningful in this regard.

### *Students' engagement in different STEM learning environments*

Based on the observational data, our results suggested that an iSTEM approach initially has a positive impact on students' collective engagement. Students' average engagement in a learning environment with an iSTEM approach was higher compared to students' engagement in a learning environment with a 'domain-specific' approach. Nevertheless, when we took the STEM learning environment's student-centredness into account in our analysis, the explained variance of the iSTEM approach for students' engagement decreased to a non-significant level, and the effect in the model disappeared. This suggests that the initial significance of iSTEM for students' engagement can be explained by a higher degree of student-centredness in this environment, rather than by the specific integrated nature of the learning environment. The results of the focus group data confirm these findings and illustrate that students who experience the iSTEM learning environment as more student-centred, express more emotional and behavioural engagement. This is in line with previous studies that found students to be more engaged in student-centred STEM learning environments (e.g. Gasiewski et al., 2012; Hampden-Thompson & Bennett, 2013; Wu & Huang, 2007).

While our quantitative data suggest that, when taking student-centeredness into account, the iSTEM approach has no significant impact on students' collective engagement, the results from our qualitative analyses show a different picture. These data suggest that the integration of STEM content and the use of authentic real world problems (problem centred learning) is experienced as engaging for students. Our study shows how this was the case if the (in)direct relevance of the subject matter became clearer for students.

Taking the above results into account, we can conclude that applying an iSTEM approach in the STEM learning environment is good practice to promote students' engagement as it seems to facilitate the teachers' implementation of a general student-centred approach. Considering the need to engage and prepare students in STEM, these results are important as previous research highlighted the significance of students' engagement in STEM for other learning outcomes, such as students' achievement, skill development and academic learning (Bathgate & Schunn, 2017; Reeve, 2012; Skinner et al., 2017). However, we highlight, in line with Nadelson and Seifert (2017), the importance of a good implementation of iSTEM education and teachers' professional mind-set.

In this study, we found that it is especially important for students' engagement that teachers apply a student-centred approach within iSTEM and adopt a professional mind-set as 'coach' during instruction. In order to facilitate a good implementation, it is important that schools are aware of teachers' attitudes towards iSTEM, as previous research found that these can influence teacher' instructional practices critically (Thibaut, Knipprath, Dehaene, & Depaepe, 2018). Moreover, previous research indicated that the school context and, in particular, the support, guidance and leadership of school principals are vital if teachers are to make major shifts from a teacher-centred to a student-centred approach (Thibaut et al., 2018b).

### *Student-centred principles and students' engagement*

Regarding the specific student-centred principles, the quantitative results show that the overarching student-centred principle 'lesson plan and implementation' was significant for students' collective engagement. The focus group data illustrate that students generally appreciate this and express emotional engagement when they are considered as a learning community. These findings imply that STEM teachers can promote students' engagement by actively appealing for students' knowledge and ideas by, for example, initiating discussions in the class group about scientific ideas or engineering design. Moreover, we found evidence that it is also important for students' engagement that the focus and direction of the lesson is consequently regularly determined by ideas originating from the students themselves. Teachers can therefore support students' autonomy by providing them with a choice (Stroet, Opdenakker, & Minnaert, 2013) on the learning content and approach. Students in one of the focus groups expressed their emotional engagement about the fact that the teacher provided a (limited) degree of freedom about what could be programmed during one of the iSTEM lessons. Another manner to provide students with choice could be, for example, choosing a project based on the interests of the whole class group.

The overarching student-centred principles 'communicative interactions' and 'student-teacher relationships' were both significant for students' collective engagement. Communicative interactions in the classroom are basically an indicator of how the other student-centred principles are implemented in the learning environment. As the other two principles were significant in this study, it is therefore not surprising that communicative interactions were also found to be important. Regarding the principle 'student-teacher relationships', the qualitative data make clear that is not only important that teachers let initiative come from the students, but that they also need to provide them with enough guidance. In one focus group, for example, all students experienced a lack of help due to the teacher's high expectations of the STEM class. This resulted in emotional disengagement. In contrast, respondents who were engaged experienced enough help as the teacher was giving sufficient hints and would show an example of an exercise when students were completely stuck while solving a problem or exercise. Brush and Saye (2000) found similar results in a study evaluating the implementation of a technology-enhanced student-centred unit. Their results showed that students felt lost or overwhelmed when the teacher did not provide enough structure, by acting as a non-participant observer in the classroom instead of a resource and coach for students.

Previous research has already highlighted the need for teachers to provide structure, as this has been found to increase students' feelings of competence, which affects, in turn, students' engagement (Reeve, 2012). In the context of the iSTEM approach, this underlines the importance of a good implementation of the iSTEM key principle 'cooperative learning' (Thibaut et al., 2018a), especially for students for whom a student-centred learning environment includes high degrees of novelty. This principle emphasises teachers' guidance, in contrast to 'collaborative learning', where the teacher will not actively monitor the different student groups and will refer all substantive questions back to the group to resolve (Matthews, 1995; Thibaut et al., 2018a). Along the same lines, Baeten et al. (2013) highlight the importance of gradually moving from a teacher-centred approach to a student-centred approach. Thus, students may adjust their role to the new approach (Baeten et al., 2013). Moreover, this could also be important for teachers who lack experience with student-centred teaching. Their role in a student-centred learning environment as a coach and facilitator, instead of a dispenser of knowledge, becomes more complex. Moreover, our data also suggests that teachers might have difficulties with time-related aspects in a student-centred learning environment, and this, in turn, can have an impact on students' engagement. The next quote gives an impression of the challenge teachers might face, of giving students sufficient freedom to work on their project, but, also, finish the instruction of the provided learning material in time.

| | |
|---|---|
| Emma: | In the first semester it was all a bit chaotic, because some things seemed to be wrong. But now it is better. |
| Jessica: | Yes now it's much easier. |
| Emma: | Yes, the first semester was still a bit searching<br>(….) |
| Jessica: | I did not like the project with the car. We also didn't finish it. |
| Thomas: | Yes sometimes it was wrongly estimated. We got two lesson hours to make a lightbox and finally we worked six or seven lesson hours on it. That lasted a long time. |
| (FG6) | |

Strong professionalisation programmes to educate STEM teachers for the complex role of coach and facilitator, are therefore needed. An important aspect to focus on in such professionalisation programme is the challenge of balancing the provision of enough autonomy on the one hand and structure on the other hand.

### *Study strenghts, limitations and future research*

The mixed-method approach, using observational data and focus groups, is an added value in this study. Only a few other studies used a mixed-method approach, including qualitative data, to investigate students' engagement in relation to the STEM learning environment (e.g. Gasiewski et al., 2012). Most studies within science education literature measure students' engagement by making use of self-report questionnaires (e.g. Bathgate & Schunn, 2017; Hampden-Thompson & Bennett, 2013; Skinner et al., 2017; Wu & Huang, 2007). Sinatra et al. (2015) argue that each method to measure engagement in science has strengths and weaknesses. The use of observational protocols has the possibility of observer bias, such as seeing what one is looking for. On the other hand, self-report has the problem of retrospection. Combining observations with focus groups to measure students' engagement was therefore an advantage in this study.

By using observations we eliminated retrospection, because the observations were made in 'real time' (Sinatra et al., 2015). On the other hand, the focus group data increased the validity of the observational data. Moreover, they gave more insight into these quantitative data by providing a detailed description on how students' engagement occurs in relation to different STEM learning environments.

A limitation of this study is that engagement was measured at the class group level, which did not allow us to compare students' engagement across different student groups, such as low-achieving and high-achieving students (e.g. Wu & Huang, 2007). Further research, investigating the importance of the iSTEM approach for students' engagement could therefore measure students' engagement at the individual level. Future research can additionally map how different STEM learning environments can have an impact on students' long-term engagement. Moreover, it would be valuable to investigate students' engagement and interactions within different STEM learning environments in a culturally different context, as the cultural context in this study was now bound to compulsory secondary education in a Flemish context. It is possible that students' engagement in iSTEM differs in a different cultural context. Furthermore, other studies investigating the significance of iSTEM for students' engagement can study the impact of the different key principles of iSTEM (Thibaut et al., 2018a) for students' engagement, as we focused on iSTEM as a general approach and the overarching student-centred principles.

## Conclusion

In conclusion, this study found that grade 9 students express more behavioural and emotional engagement in STEM learning environments including a higher degree of student-centredness. The main finding is that, applying an integrated STEM (iSTEM) approach is a good practice to promote students' engagement in the STEM learning environment, as it facilitates teachers' implementation of a general student-centred approach. These findings are innovative as, to the best of our knowledge; no other studies investigated which role iSTEM education can play in promoting students' engagement.

# CHAPTER 5

5

# Study 4:

## Understanding student engagement in STEM learning environments: A multiple case study.[7]

7 This chapter is based on: Struyf, A., Boeve-de Pauw, J. & Van Petegem, P. (2019). Understanding student engagement in STEM learning environments: A multiple case study. Submitted

## Abstract

Engaging students in STEM is an important societal need. Therefore, it is important to gain insight into which factors students experience as engaging or constraining for their engagement within diverse STEM learning environments. In this study, we applied a multiple case study and followed ten grade 9 students. We collected data through interviews and logbooks over the course of one complete academic year. Both students who followed an integrated STEM (iSTEM) curriculum and students following a non-integrated STEM curriculum are included in the study. The results identify several factors that are critical for (changes in) students' engagement in diverse STEM learning environments. From the students' point of view these are: collaboration, the quality of relationships with peers and teachers, hands-on activities, subject matter and time-related aspects. The results suggest that iSTEM education is a practice that can engage students in STEM as it facilitates the implementation of collaborative activities with peers and hands-on activities. However, the results show that, especially during these activities, the quality of relationships with peers and the teacher's role as a coach is crucial to enable students' engagement. We discuss implications for practice and explore possible routes for further research.

## Introduction

Over the past decade, science education literature and policy has strongly highlighted the need to engage students in Science, Technology, Engineering and Mathematics (STEM). This is not only important in order to provide the labour market with highly qualified STEM professionals, but also to give all students sufficient literacy with regard to STEM in our highly technological societies (World Economic Forum [WEF], 2017). The fact that, despite the overall importance and presence of STEM throughout societies, many students tend to disengage from STEM, deserves scholarly attention (Bøe, Henriksen, Lyons, & Schreiner, 2011; Organisation for Economic Co-operation and Development [OECD], 2008).

Policymakers and an increasing amount of literature draw attention to the manner in which STEM is taught in compulsory education as a significant factor contributing to the disengagement of students in STEM (Archer et al. 2010). In many primary and secondary schools, STEM education focuses on theory, rather than on application and experiential learning. This reinforces a disconnect between the different STEM disciplines and the "real world" (Struyf, De Loof, Boeve-de Pauw, & Van Petegem, 2019; World Economic Forum [WEF], 2017). A shift towards more authentic, student-centred learning environments is generally assumed to be necessary to increase students' interest and engagement in STEM (Gasiewski, Eagan, Garcia, Hurtado & Chang, 2012; Sawada et al., 2002; Skinner, Saxton, Currie, & Shusterman, 2017).

A promising educational approach in this regard is integrated STEM education (iSTEM) (Koul, Fraser, Maynard, & Tade, 2017; Thibaut et al., 2018a). The starting point in an integrated STEM curriculum consists of challenging students to solve an authentic "real-world" problem that cannot be solved through the application of one single STEM discipline. Consequently, students need to simultaneously apply knowledge and skills from different STEM disciplines (Nadelson & seifert, 2017). As problems requiring an iSTEM approach are typically ill-structured with multiple solutions, iSTEM education requires a student-centred learning environment (Moore & Smith, 2014; Nadelson & Seifert, 2017). Typically, both students and the teacher take on a different role in a student-centred learning environment, compared to a traditional teacher-centred learning environment (Anderson, 2007; Brush & Saye, 2000). In iSTEM, the teacher is a "coach" rather then a dispenser of knowledge, and students are active learners. They analyse and synthesise the learning content themselves, facilitated by the teacher. The students need to examine these complex real-world problems by using a variety of means and need to develop their own strategies to solve them in collaboration with others (Anderson, 2007; Brush & Saye, 2000).

As integrated STEM education is a new educational approach, little research on students' engagement has been carried out in this type of learning environment. Additional research that investigates factors that enable or constrain students' engagement in this type of learning environment is therefore necessary (Struyf, De Loof, Boeve-de Pauw, & Van Petegem, 2019). Research that focuses on students' engagement in non-integrated STEM contexts, already offers insights about which factors within a learning environment can play a role for students' engagement in STEM.

However, these studies are mostly quantitative in nature (e.g. Hampden-Thompson & Bennett, 2013; Skinner et al., 2017). It remains unclear which specific aspects within STEM learning environments are of chief importance for students themselves regarding their own engagement in STEM. Therefore, our current study applies a more holistic approach, investigating qualitatively which experiences within different STEM learning environments were crucial for grade 9 students' engagement over the course of a complete school year. We applied a multiple case study involving students who followed an iSTEM curriculum, as well as students who followed a "traditional" curriculum. Hence, we aim to contribute to the literature by, first, using a qualitative approach to study students' engagement in STEM. Second, we aim to offer more insight into which aspects within a specific iSTEM learning environment can be crucial for students' engagement.

## Theoretical framework

### *Student engagement*

We conceptualise *engagement* as "the behavioural intensity and emotional quality of a person's active involvement during a task" (Reeve, Jang, Carrell, Jeon, & Barch, 2004, p. 147). Students who are *behaviourally* engaged, work hard, take initiative and persist during challenging learning activities. Moreover, they are *emotionally* engaged during these learning activities if they show interest, enthusiasm and zest for learning. In contrast, disengagement or *disaffection* is evident in students who are bored, passive and give up easily (Skinner, Furrer, Marchand, & Kindermann, 2008; Skinner et al., 2017). Engagement is an important educational construct as it has been found to cause many favourable student outcomes, such as academic learning, achievement, skill development, and academic resilience (Reeve, 2012; Skinner et al., 2008). Researchers have also hypothesised that consistent engagement can lead to long-term involvement in schooling. For this reason the concept became of particular interest for its role in promoting persistence in STEM education and a STEM career choice (Sinatra, Heddy, & Lombardi, 2015).

Sinatra et al. (2015) argue that engagement can be theoretically placed on a continuum, with a person-oriented approach at one end and a context-oriented approach at the opposite end of the continuum. The main focus in the person-oriented approach is an individual's engagement with a specific topic or task. In the context-oriented approach the focus is on capturing the characteristics of the social context such as a classroom or school and how these afford or impede engagement. A person-in-context approach resides in the middle of the continuum. Here, researchers aim to understand and describe how students interact with others, as well as with dimensions afforded by the social context (e.g. classroom instruction, technology) and how a particular type, level or form of engagement occurs (Sinatra et. al, 2015). In this research, we study engagement from the latter perspective.

### *Critical factors for students' engagement in STEM learning environments*

Skinner et al. (2017) offer valuable insight into which factors are determinative for students' engagement in STEM classes. Their theoretical model builds on self-determination theory (SDT), which states that people have three basic psychological needs, namely: autonomy, relatedness and competence (Deci & Ryan, 2002). In an educational context, students' need for *autonomy* is met when students feel a sense of ownership towards their own work. The need for competence is met when students feel successful and capable, for example, in completing their coursework. Students' need for *relatedness* is fulfilled when they feel connected or have a "sense of belonging" towards their class and classmates (Deci & Ryan, 2002; Skinner, 2017). Furthermore, SDT literature posits and continues to find that the fulfilment of these needs leads to higher well-being, motivation and also engagement (Deci & Ryan, 2002; Reeve, 2012).

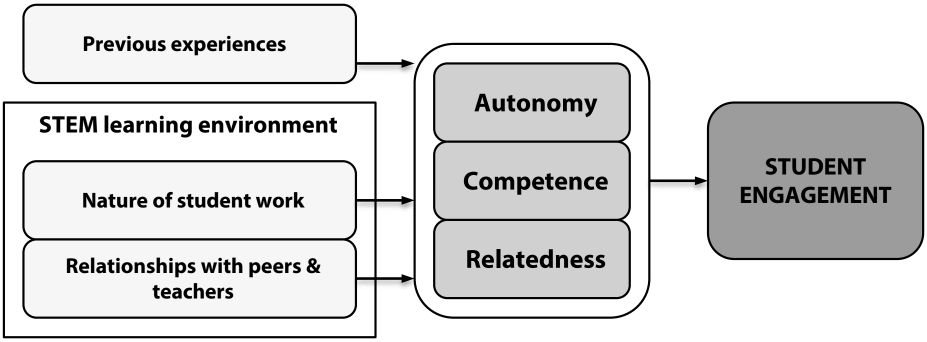



**Figure 1:** Self-determination theoretical model of motivational processes in science classes (based on Skinner et al., 2017)

Skinner et al. (2017) distinguish three main components in their theoretical model that will predict students' sense of autonomy, relatedness, competence, and thus, in turn, students' engagement in STEM (see Figure 1). The first is related to students' previous experiences in STEM, such as preparation and performance. The second contributing factor is the nature of the student work. Skinner and colleagues (2017) argue that students' engagement can be fuelled by student work that is "hands-on, heads-on, experiential, project-based, authentic, relevant, progressive and integrated across subject matter" (p.2437). iSTEM education matches the requirements of this type of student work. The last factor distinguished by these authors is the supportiveness of students' current relationships with classmates and the teacher.

Other quantitative studies that were carried out in a STEM educational context and that focused more in depth on the role of these factors, confirmed the significance of these factors for students' engagement. One study that focused specifically on the role of teachers' motivating style, in terms of supporting basic psychological needs of students, showed that the teacher's provision of autonomy support and structure contributed to students' collective classroom engagement in both integrated and non-integrated STEM lessons. Surprisingly, no relation between teachers' involvement, which is assumed to fulfil students' need of relatedness, and students' engagement was found (De Loof, Struyf, Boeve-de Pauw and Van Petegem, 2019).

Regarding the nature of student work, research by Hampden-Thompson and Bennet (2013), investigated the variance in students' self-reported engagement in science across various teaching and learning activities. Their study revealed that higher levels of students' emotional engagement were especially found in classrooms in which students reported higher levels of interaction, applications in science and hands-on activities. One mixed-method study by Struyf et al. (2018) that investigated the role of a learning environment applying an iSTEM approach, showed that an iSTEM approach initially seemed to support secondary school students' collective classroom engagement. However, further investigation made it clear that the student-centred design of this curriculum was of particular importance, rather than the integrated nature of the curriculum. In other words, it was found that the teacher's role as coach, rather than as dispenser of knowledge, was significant for students' engagement. On the other hand, the focus group data in the study of Struyf et al. (2018), provided evidence that the integration of STEM content and the use of authentic real world problems was engaging for a number of students, so long as this made the (in)direct relevance of the STEM content clearer. Other studies, carried out in non-integrated STEM learning environments, also highlighted the role of the learning environment's student-centredness for students' engagement. The study of Wu and Huang (2007), for example, showed that students in student-centred technology-enhanced STEM learning environments were more emotionally engaged, in contrast to students in a teacher-centred STEM learning environment. Additionally, Gasiewski et al. (2012) found that students were more emotionally and behaviourally engaged in STEM classrooms in which professors applied a student-centred approach and where collaboration with others frequently took place.

In sum, based on mainly quantitative research, much is already known about some of the crucial factors that support student engagement, especially within non-integrated STEM learning environments. However, the question remains as to which aspects are most meaningful for (changes in) students' engagement from students' point of view, and how students' engagement manifests itself within different STEM learning environments. Therefore, more qualitative research investigating student engagement within diverse STEM learning environments over a longer time period is needed.

## Aim of the study

The aim of the current study is to uncover experiences that were critical for grade 9 students' engagement throughout one school year. Thus, we aim to shed light on which factors in the STEM learning environment enable and constrain engagement for a diverse range of students. The focus is on both students who follow an integrated STEM curriculum and students who follow a "conventional" non-integrated curriculum. This leads to the following research questions (RQs) that drive this study:

RQ1: In which way does grade 9 students' engagement in STEM change over the course of one school year?

RQ2: Which factors in the STEM learning environment are: (a) critical in enabling and constraining grade 9 students' engagement and (b) responsible for changes in students' engagement over the course of one school year?

## Method

### *Multiple case study*

In line with the criteria of Yin (2003), we applied a case study approach because (a) the focus of our study was to answer "how" and "why" questions; (b) behaviour of participants in the study could not be manipulated; (c) we wanted to cover contextual conditions, namely the STEM learning environment, as we assume this environment can enable or constrain students' engagement; (d) boundaries are not clear between the phenomenon and the context. As stated in the theoretical framework, engagement cannot be detached from the context in which students learn, as engagement occurs and is shaped by various social contexts.

In our study, the case was centred on ten grade 9 students' engagement. A more specific multiple-case study approach was chosen because, in addition to uncovering differences in students' engagement with regard to STEM, we also wanted to uncover differences across different formal STEM learning environments. Adopting this approach allowed us to explore differences in engagement within each setting, as well as across the different settings (Baxter & Jack, 2008).

### *Research context and procedure*

This research is embedded in the research project STEM@School. The aim of this project is to investigate which factors within diverse STEM learning environments support and facilitate students' achievement, motivation and engagement towards STEM. For the purpose of the current study, three schools among the 41 Flemish participating schools in the project were selected. To ensure variation in STEM learning environments, two schools that applied an iSTEM approach in the 9$^{th}$ grade (School A and B) and one school that did not implement an iSTEM curriculum (School C) were randomly selected from the entire set. All three schools were located in smaller urban areas in Flanders. Two schools mainly consisted of a white student population, while one school was more ethnically diverse.

School A and B have implemented three different iSTEM modules in the grade 9 curriculum since the beginning of school year 2014-2015. Each module covered one trimester. In the first module, students' were challenged with designing and building an autonomous driving car that could drive through a "green wave". During the second module pupils had to design and build a museum security system and, in the last module, a physical rehabilitation device. The design of the modules was based on the theoretical framework of integrated STEM education (iSTEM) (Thibaut et al., 2018a). This framework is founded within a general constructivist view on learning and includes five key principles that form the base to design a student-centred, authentic STEM learning environment. The first key principle is the *integration of STEM learning content*, by integrating the subject matter of various STEM disciplines purposefully into one project. Secondly, problem-centred learning refers to the use of authentic real world problems to increase the relevance of the learning content for students. Inquiry based learning, the third principle, includes engaging students in questioning, experiential learning and hands-on activities that allow them to discover new concepts and develop new understandings. Fourth, design based learning includes involving students in technological or engineering design. Finally, cooperative learning relates to teamwork and collaboration with other pupils.

Three to four participants among the grade 9 students who were willing to participate in the study were randomly selected to provide variation among students' characteristics, such as sex and career aspirations. In line with Belgian legislation, permission to participate in this research was obtained both from the students and their parents, initially through a passive informed consent procedure. Furthermore, at the start of the first interview with the participating students, active informed consent was obtained from all participants.

### *Participants*

In total ten grade 9 students, aged 14-15 years old, were selected. This is consistent with Stake's (2006) suggestion of five to fifteen cases to guarantee a sufficient but not overwhelming amount of data. The participants in this study had recently finished a more general educational track and had now opted for a more specific curriculum with a focus on STEM, from a choice of education tracks (e.g. including "economics" and "languages"). An overview of participants' demographics, vocational aspiration and school can be found in Table 1. Pseudonyms are used to protect participants' privacy.

**Table 3:** Overview of participants' demographic information and school

| Participants | Sex | Vocational aspiration | School |
|---|---|---|---|
| Kim | F | Detective or interpreter | A |
| Olivia | F | Doctor, lawyer or laboratory technician* | A |
| Nathan | M | Animal caretaker | A |
| Emily | F | Physiotherapist | B |
| Zoé | F | Radiologist or science-related profession | B |
| Bahir | M | Science-related profession | B |
| Jessica | F | Psychologist | C |
| Sarah | F | Doctor or psychologist | C |
| Max | M | Engineer | C |
| Bjorn | M | Animal related profession | C |

*Note: At the end of the school year

### *Data collection*

The primary data source for this study was individual interviews. The first author interviewed each student twice: once at the beginning and once at the end of school year 2016-2017. Between the period of the first interview and the interview at the end of the school year, participants were asked to fill in a logbook after the first and second trimester (see Table 2). This timing was aligned with the ending of a module for students who followed the curriculum with the iSTEM approach.

**Table 4:** Overview of collected data sources across the school year

| **Data collection school year 2016-2017** | |
|---|---|
| Start school year | Interview 1 (Int 1) |
| End 1st trimester | Logbook 1 (LB 1) |
| End 2nd trimester | Logbook 2 (LB 2) |
| End school year | Interview 2 (Int 2) |

The nature of the interviews was semi-structured. Questions in the interview conducted at the beginning of the school year related to students' educational and vocational aspirations, perceptions of the learning environment, their experiences with that environment and engagement with regard to different STEM courses. The interview questions focused especially on experiences and perceptions regarding iSTEM, physics and mathematics. This specification was chosen because at that stage, the integration of STEM content in the iSTEM modules for students in School A and B mainly concerned physics and mathematics. The application of content and knowledge of, for example, biology or chemistry, was not considered in these iSTEM modules. To capture students' general engagement level in the different STEM courses, students were asked to which STEM course (mathematics, physics or iSTEM) they most like to go and why. Additionally, the researcher gave the student a list of emotions and behaviour, based on Skinner et al.'s (2008) motivational conceptualisation of engagement and disaffection in the classroom. Students could indicate which emotions and behaviour they recognised in themselves during mathematics, physics, and if applicable iSTEM. Emotions that were included in this list expressing emotional (dis)engagement were, for example: "satisfied", "interested", "proud", "bored", "frustrated". Examples of described behaviour were; "active", "absorbed", "involved", "distracted", "unprepared". The students could also specify that this feeling or behaviour occurred only sometimes. Subsequently, the researcher asked for clarification of students' chosen behaviour and emotions. The researcher also stated that students could ask her the meaning of the emotions and behaviour if this was not clear.

The log books consisted of a short questionnaire in which students could describe one mathematics, physics or iSTEM lesson that they found the most "pleasant" and one lesson that they found the "least pleasant" during the last trimester. They could also indicate why they chose this lesson, selecting between four options a) type of student work (e.g. making exercises, listening, teamwork, …), b) the teacher, c) lesson content, d) other. Students who selected option a, b or d were asked to clarify their choice (e.g. "What did you have to do during this lesson that you found (un)pleasant?" "What did the teacher do that you found (un)pleasant?").

The logbooks were sent to the students' e-mail or to a secretarial staff member who delivered the logbooks to the students and collected them afterwards. The confidentiality of these data was emphasised and communicated in advance to the staff member involved.

In the interview at the end of the school year, the researcher discussed with the student whether there was any change in the student's educational or vocational aspiration(s), as well as their engagement level in, and experiences with, the different STEM courses. Additionally, the experiences that students wrote down in the logbooks were discussed.

Combining the two data sources of interviews and logbooks in this study,  served as a triangulation strategy to increase the validity of the data. Both the interviews and the logbooks were gathered for the same purpose, namely investigating experiences that were meaningful and critical for students regarding their engagement in the STEM learning environment. Moreover, in the last interview, the researcher discussed the logbooks together with each participant. This allowed us to review how meaningful the lessons mentioned in the logbooks were for the participant and seek clarification in case some data was missing, or if something was unclear for the researcher. The interview time of both interviews lasted approximately 40 to 70 minutes.

### *Analysis*

For the analysis of our data, we followed an analytical approach in line with the methods described by Miles and Huberman (1994). They describe three categories of data analysis strategies including: a) a case-oriented approach, in which the individual cases are of primary importance, b) a variable-oriented approach, in which the variables across various cases are of central importance and fine-grained details of specific cases may be consequently lost, c) a mixed strategy, in which a combination of the two approaches is used.

Similar to Matusovich, Streveler and Miller (2010) who applied a multiple case-study, we applied the mixed strategy and started by grouping our data (two interviews and logbooks) by case. Subsequently each case was analysed separately to map changes in students' individual engagement during the school year and investigate which experiences were critical in this regard. Therefore, the recorded interviews were transcribed and (re)read to become familiar with the data. Initial codes and reflections were added to the transcripts throughout this process, using pencil and paper. Students' expressions of emotions and behaviour in the transcript were labelled, using the motivational conceptualisation of engagement and disaffection in the classroom provided by Skinner et al. (2008); e.g. "bored - emotionally disaffection". Examples of other initial codes are: "enthusiasm teacher" or "can not sit still". Students' engagement level for each STEM related course (mathematics, physics, iSTEM) was categorised as low (L), medium (M) or high (H) based on students' self-reported engagement and their clarification in the interview. For example, when the student indicated to be only or mostly emotionally and/ or behaviourally engaged during mathematics and stated that this was his/ her favourite course throughout the interview; the engagement level for mathematics was categorised as "high". When students' self-reported engagement resulted in a mix of engagement and disaffection, or when the student indicated to be sometimes (dis)engaged during the lessons of a particular course, the engagement level for that course was labelled as "medium". Correspondingly, the engagement level was categorised as "low" if the respondent reported to be mostly or always disengaged. Finally, critical experiences within the STEM learning environment were listed as per each individual case. Obviously, experiences within lessons that were mentioned in the logbooks by the student as pleasant were considered as experiences in favour of that student's engagement. Unpleasant experiences were considered as disengaging experiences.

We began with the variable-oriented approach, by applying a thematic analysis (Braun & Clarke, 2006), using the qualitative data analysis software Nvivo 11. The initial codes across the whole data set were entered and gathered under broader codes that reflected key themes within the interviews (e.g. engagement, disaffection, reason of study choice, independent work iSTEM, collaboration with peers, teacher). Coding during this step of the analysis was data-driven. Next these thematic codes were reviewed in relation to the coded fragments and the entire data set, with a thematic map of analysis as a result. Specifics of each theme were refined when necessary. During this step of the analysis, we applied a theory-driven approach for the theme "teacher", based on literature concerning teachers' basic psychological need support (De Loof et al., 2019; Reeve et al., 2004). Finally, vivid quotes of the students were selected and further analysed in relation to the research questions that govern this research.

## Results

First, we give a general overview of students' individual engagement level, at the beginning and at the end of the school year, per STEM related course. Next, we discuss, which experiences with factors in the STEM learning environment were meaningful for each case, and across the cases. We also discuss to what extent these experiences within the learning environment were responsible for changes in students' engagement level during the school year.

### *Students' engagement level and development through grade nine*

An overview of changes in students' engagement level can be found in Table 2. Some interesting patterns in the development of students' engagement are present. A first observation is that for most students, individual engagement levels per course at the end of the school year remained similar to those at the beginning of the school year. Secondly, higher engagement levels among these students can be found for mathematics and more medium engagement levels for physics. When changes in students' engagement level occurred, this was mostly a negative change. In other words, students' engagement developed towards increased disengagement, an exception being Emily's engagement regarding iSTEM.

**Table 5:** Overview of participants' engagement level in STEM through grade nine

| | Respondent | MATHEMATICS | | PHYSICS | | iSTEM | |
|---|---|---|---|---|---|---|---|
| | | Beginning | End | Beginning | End | Beginning | End |
| School A | Kim | H | M | M | M | M | L |
| | Olivia | H | H | L | L | H | H |
| | Nathan | H | H | H | H | H | H |
| School B | Emily | H | H | M | M | M | H |
| | Zoé | H | H | H | H | M | M |
| | Bahir | L | L | H | M | H | H |
| School C | Jessica | M | L | H | M | | |
| | Sarah | H | H | M | M | | |
| | Max | H | H | M | L | | |
| | Bjorn | H | H | M | M | | |

### *Critical factors for student engagement from students' perspective*

Reported factors in the STEM learning environment that were meaningful for (changes in) students' engagement across the different cases were related to collaboration, relationships with peers and teachers, the nature of student work, the subject matter and time-related aspects. We will discuss these themes in this order in more detail in what follows and describe the meaningful experiences of the different cases as they relate to each theme.

### *"Yes collaboration is fun, but it depends with who"*

Generally, collaboration with others was a factor that enabled students' engagement in STEM. All participants mentioned that they value *collaboration with peers* and prefer collaborating over working alone. Students in both the iSTEM and the conventional STEM curriculum state that through "collaboration you help each other" and "learn from each other". Olivia additionally adds that collaboration is especially fruitful during iSTEM, because topics there are complex and collaboration can facilitate meeting deadlines more efficiently. Moreover, she explicitly mentions that she enjoys collaboration in iSTEM because "in many professions you also need to collaborate". However it was the *quality of the relationships* with others that was critical for certain students' engagement in the STEM learning environment during the school year. This was especially the case for Emily, Zoé (School B) and Kim (School A). Kim found the iSTEM lessons to be the least pleasant lesson, as stated in both logbooks and cited the group work as the reason why in the second logbook, in conjunction with the lesson content.

Kim: Two of my group are not cooperative and that's why Olivia and me need to do all the work. If we then ask what they want to do, they don't know it. If Olivia and me then choose ourselves what we do, they agree. And then if I ask how much they progressed with their work, it turns out that they did not do anything for five lessons of two hours. Which means that we need to do everything. But next time I will not make that mistake any more and do only what was agreed upon at the beginning.

(LB1)

For the first trimester in School B, the students were assigned to groups by the teacher for some lessons and during other lessons they could choose their own groups. Both Emily and Zoé mentioned in the logbooks that they experienced the iSTEM lesson(s) with the assigned groups to be the least pleasant due to the group work. For example, Zoé, mentioned that; "The pupils with who I worked were sympathetic, but we don't have affinities". Also in the interviews she mentioned that the group work was "boring", for this reason.

On the other hand, Zoé picked out the iSTEM lesson with the self-chosen groups as the most pleasant in the first logbook and an engaging lesson in her experience:

Zoé: I liked it [working in groups] because we could choose with who we worked so it was much more pleasant. During the last lessons we could not choose with who we worked and we worked for a long time with the same group, maybe to get to know each other better because we all came from different classes.

(LB1)

Emily was especially disappointed by the group work, because she had a similar experience to Kim with a group that was not cooperative. In the first logbook she wrote: "I didn't understand it myself very well, but tried my best while the rest just copied if I found something". In contrast to this experience she mentioned in the last interview that the group work during the other modules was "fun", because she could cooperate with her friends. She states: "So you have fun, while you're also working well and progress much faster". Thus, this experience enabled her engagement critically.

## *Highly engaged students, taught by highly engaged teachers?*

The teacher was very crucial for certain students' engagement in the STEM learning environment and was a factor that could either enable or constrain students' engagement. It was, for example, very remarkable that all participants from School A were found to be both highly emotionally and behaviourally engaged for most mathematics lessons, because they enjoyed the teacher's instruction of the learning material and the atmosphere in the class. They all described the teacher as "enthusiastic, fun and helpful".

Nathan: They are fun [the other teachers], but like the one for mathematics; he is for example really jumping around in the class. The ones for physics and iSTEM don't do this. That is why mathematics is a bit more fun.

(Int 1)

Olivia Mr. X [mathematics teacher] likes it if you ask a question. He's really like: "Yes, ask please!" So that's nice.

(Int 1)

Based on the descriptions of these students' experiences in the logbooks and interviews, we can infer that this mathematics teacher was not only spreading his enthusiasm in the class, but that his teaching style was also very autonomy supportive. The following quote retrieved from Kim's logbook clearly illustrates the mathematics teachers' autonomy and competence support.

Kim: The teacher gave me compliments if I did well and taught me to discover my own mistakes if something did not go well. If I finally didn't find it out, he made an exercise on the whiteboard and then I had to tell how I calculated something. Then he told me what I did wrong.

(LB1)

Both Olivia and Kim also found the mathematics lessons to be the most pleasant lessons in the STEM learning environment, stating so both in the first and second logbook. They stated that the teacher was the determinative factor, besides Olivia's strong personal interest for mathematics. On the other hand, experiences with (other) teachers were also constraining students' engagement and were even determinative for more disengagement. This was again the case for Olivia and Kim who experienced and described the physics teacher, in contrast to the mathematics teacher, as "not helpful in answering questions well" and "stubborn". Moreover, they mention that the teacher becomes angry when they would make a mistake, do not understand something, or correct him. Olivia, for example, stated the following in the interview at the beginning of the school year:

Olivia: The teacher of physics is actually not a very good teacher because he is not really asking questions, or if I don't understand something I just need to learn it by heart, instead of that I get explanation about my question. Our physics teacher is also very stubborn sometimes. Especially if you don't agree with something, he can become really angry.

(Int 1)

This experience constrained both Olivia's and Kim's engagement regarding physics. Especially for Olivia as, at a later part of the interview, she describes her engagement level during physics as follows:

Olivia: Sometimes I feel like withdrawing because there is not much point in asking. I try to pay attention in physics, because I know I have some difficulties with it. But then regarding feelings, these are mostly negative feelings. I think just because of the teacher but also because I don't understand it.

(Int 1)

Based on the quote above and her described behavioural engagement in the physics class, it can be understood that Olivia tried her best to be behaviourally engaged by paying attention and being involved. Nevertheless, her experience with the teacher made her withdraw and resulted in her being emotionally disengaged. More specifically, she could recognise herself during the first interview as having the following feelings towards physics: bored, not interested, frustrated/ angry, sad, anxious/worried. Also in the first logbook she assessed one of the physics lessons as the least pleasant lesson because the "teacher could not explain it himself and no one understood something of the lesson".

During the interview at the end of the school year, she mentioned that she was no longer behaviourally engaged during physics. Aside from having little interest in the content, another determinative factor was a new teacher who replaced the teacher of the first semester. In the second logbook and the interview she expresses a sense of dislike towards this teacher and states that she feels the teacher underestimates the pupils by treating them "like babies". In the last interview she adds that the teacher is also not strict enough towards certain students and states that those experiences "do not really make the lessons more interesting, as she found physics already not very interesting."

As both physics teachers also co-taught with another teacher during iSTEM, this also partly constrained Kim's engagement in iSTEM. This was the case in the beginning of the year. In the first interview she mentioned that she had experienced a lack of clear instructions during iSTEM, which constrained her engagement.

| | |
|---|---|
| Kim: | Sometimes I think, "OK I am bored, … but I will continue." |
| Interviewer: | And what are such moments that you are bored? |
| Kim:<br><br>(Int 1) | Calculating the velocity. We had to make a car and calculate how fast it drives, but I don't understand this teacher. He does not explain it well. He says: "you have to obtain this, you can start." |

In the last interview, she claimed to be also bored by the teacher's instructional approach for the same reason as Olivia, besides her negative experience with the group work and the lesson content.

| | |
|---|---|
| Kim: | It's not really my game, this revalidation thing. |
| Interviewer: | So it's about the subject. |
| Kim:<br><br>(Int 2) | I think it also has a lot to do with the teacher, because in the 7th grade we had a good teacher [technology course] and that was fun. But I really don't like the teacher we have now… The way of teaching just bores me. |

Also Bahir's (School B) experience with his mathematics teacher, besides the lesson content, was critical in constraining his engagement during mathematics. During the interviews he appears to have been both behaviourally and emotionally disengaged during the mathematics lessons in terms of being distracted and worried/ anxious. In his first logbook he experienced one of the mathematics lessons as the least pleasant lesson of the first semester due to the teacher. He claimed to not understand the lesson content and mentioned that, "If you asked a question, the teacher barely answered. Then you couldn't proceed and she became angry."

### *"I cannot sit still, I need to move during the class"*

Hands-on activities, such as experiments, and research and design activities, were factors that enabled the engagement of nearly all participants in STEM. Only Kim found the research and design activities, such as placing a motor, boring. Also Max (School C) stated that he would not enjoy too much practical content in the curriculum because he did not find himself to be a hands-on person, but he enjoyed doing experiments during physics. Nevertheless, experiences with this type of learning activity were only critical for few cases in this study. The *research and design activities* implemented during the iSTEM lessons were, for example, crucial for both Nathan's (School A) and Bahir's (School B) engagement. For both students, iSTEM was their favourite STEM related course (among iSTEM, physics and mathematics). Bahir also chose one of the iSTEM lessons as the most pleasant lesson, in both logbooks. The experience of freedom and autonomy during iSTEM was the most relevant aspect to him, as he mentions in his interviews. For the opposite reason, his engagement in mathematics was constrained because he had to "sit still" in those lessons and did not experience the same level of freedom in solving problems:

| | |
|---|---|
| Bahir: | It's just a nice course [iSTEM]. You are free. The teacher says "you need to do this now" and then you are free, because you can do with your group what you want; you can decide yourself if you can do it this way or that way. So that's really interesting. (…) For example, now we are busy with building that car and with meters per second. We have to let the car drive and everyone had his own way to do this. (…) It is for example not like mathematics. Mathematics is making exercises and it is always done in the same way; you have the formula, you need to use the formula. In iSTEM it's different, the teacher just gives you the basics. He says you need to do this on the computer and then you just do it in your own way. |
| (Int 1) | |

Compared to Bahir, Nathan stated that he especially enjoyed calculating, designing and building during all the modules. In addition the trial and error process inherent to research and design activities, in conjunction with the experience of success, was a critical event for several students' engagement. It lead to intense emotional engagement, such as feelings of pride, interest and enthusiasm. Bahir, for example, claimed to be proud during iSTEM "when you're doing well and achieve your goal". The following quotes from Olivia and Bahir, further illustrate this.

| | |
|---|---|
| Olivia: | Our whole car was inspired by a drop of water. First we thought that our car completely failed, because it went so slow. Then we recalculated and input everything, and at a certain velocity it just went slower. Then we let it drive along the route and suddenly something clicked. I think we did not attach a string well, and suddenly it went so fast! So then we were quite proud! |
| (Int 2) | |

| | |
|---|---|
| Bahir: | The module with the museum was really fun. (…) Before we had to build the museum, we saw a short film clip of someone who wanted to break into a museum. I thought when I saw that film, that it would be really boring. But then, when we started to build it up step by step, I really liked it. You have a laser and directly when you interrupt it by putting your hand through it, the alarm went off. I wouldn't think it would have such an effect. |
| Interviewer: | So you did not expect the alarm would really go off. You really tried it out. |
| Bahir: | Yes, because we tried it several times on the computer programme and then we thought it wouldn't succeed. But then at the end it worked out. |
| (Int 2) | |

Moreover, the process of trial and error was an important learning experience for Nathan. This experience was also critical for his behavioural engagement in iSTEM, in terms of persistence.

| | |
|---|---|
| Interviewer: | Are there things that you found remarkable yourself about the last year? Something that stick in your memory or something you learned a lot of, from iSTEM, mathematics or physics? |
| Nathan: | Yes, from the iSTEM lessons I really learnt that if you bump into a problem while you are making something, you will finally solve it; but you need to put effort towards it. You don't need to think "it will come naturally". You need to make an effort. |
| Interviewer: | Can you give an example of that? Something you faced throughout the lessons? |
| Nathan: | Yes, when we had to make our car, we faced the problem that it wouldn't drive. Then we searched for a long time for what could be wrong. After a while we found out why and then it drove again. |

(Int 2)

In contrast to these experiences that enabled students' engagement, Emily had some difficulty with the autonomy experienced during the first module of iSTEM. She indicated that it was "fun" to design the car, but sometimes she was also "bored" because she was not used to the independent work during programming. As their class was combined with another class for the instruction of iSTEM, she also stated that this made the class "noisy". Moreover, she added that this made it sometimes hard to ask questions, as there were only two teachers to help all students. This indicates that she experienced a lack of help and guidance. This experience, combined with her experiences with non-cooperative group work in the beginning of the school year, was critical for her engagement levels.

| | |
|---|---|
| Emily: | If you need to program on the computer it is mostly independent work and then I don't know very well what to do. That's difficult sometimes. But it is also fun, because we're now busy with a project of designing cars and making them to drive. So I like the pleasure of making it. But the programming is sometimes a bit boring, because I don't know it very well. |

(Int 1)

However, Emily enjoyed the programming during the second module about the museum security system more, as it was not the first time she had attempted the task and so she felt more confident.

Besides the meaningful experiences of these students during the iSTEM course, experiments during physics were a critical factor that enabled Jessica's (School C) engagement in the STEM learning environment. In the interview she mentions that she especially enjoyed doing experiments during physics. In addition, she chose a physics lesson as her most pleasant lesson in both logbooks and highlighted the experiments as the main reason for this choice. In the first logbook she wrote: "I liked the experiments to show how something works and it also makes it much easier to understand the lesson content. It also makes the lesson more fun."

### *"I just love mathematics, it is like the ballet of the courses"*

Not surprisingly, the curriculum itself was critical for some students' engagement, regardless of, or in addition to, other aspects in the learning environment. Sometimes this was related to the students' personal interest in one specific STEM discipline, but sometimes it was also related to a specific topic within the curriculum. With the exception of Kim, all participants with high engagement levels for mathematics had a strong interest in mathematics. Zoé (School B), for example, mentioned during the interview that she mostly liked to go to the mathematics lessons. When the interviewer asked the reason, she said that "she had just always liked it".

Max (School C) for example, stated that he preferred solving mathematical issues over exercises in physics. When the interviewer discussed the difference in his engagement level between mathematics and physics, he stated the following:

| | |
|---|---|
| Interviewer: | So especially during mathematics you're active, making an effort, being persistent and so on? |
| Max: | Yes, more during math than physics. |
| Interviewer: | You said you found the mathematical formulas nicer? |
| Max: | Yes, I think if I like to do that more, I will also show more effort. |
| Interviewer: | Are there other things that might explain the difference? |
| Max: | No I think that's why, because we have also the same teacher [for both physics and mathematics], so it can't be about that. |
| Interviewer: | And imagine you would be the teacher yourself; are there things you would approach differently? For example, for physics or even mathematics? |
| Max: | Oh, I don't know. Not really. |
| (Int 1) | |

At the end of the year, Max also indicated that both his emotional and behavioural engagement with respect to physics had dropped, because he did not enjoy the subject matter any more: "In the beginning it was 'just' the beginning and then it was still quite nice. Then the subjects were nicer, but then when it came to the refraction of light, I really did not enjoy it. Then I also don't feel like doing it." When the interviewer, asked again if he would approach the lessons differently, he stated that he would not change the approach because it was "nicely done, with light and so on", but that it was just the subject that he did not find interesting.

Similarly to Max, Olivia, also stated a preference for mathematics over physics. This was not only related to her experiences with the teacher and her feelings of competence. She also considered that the subject matter was better suited to her identity, as she labelled herself a "perfectionist":

| | |
|---|---|
| Interviewer: | To which lessons do you prefer to go, if you have to choose between mathematics, physics and iSTEM? |
| Olivia: | Especially mathematics. I find it very beautiful and I'm also very good at it. And the teacher is funny. (…) |
| Interviewer: | You just mentioned "I find mathematics beautiful". What do you mean exactly by that? |
| Olivia: | I find it actually, how should I say it, … the ballet of the courses. Because not everyone appreciates it, but if you look very closely at it, it is really beautiful. Mathematics can be difficult, but I just find it very beautiful. How all these mathematical calculations perfectly fit into each other, it's just perfect. That's probably because I am a perfectionist. The rules are just there, without exceptions, while for French you have for every rule an exception. I think that's what I find most beautiful about mathematics. |
| Interviewer: | So that it fits all well into each other. |
| Olivia: | I find it actually one big puzzle and I've always liked puzzles, already as a little kid. |

(Int 1)

While these students were especially interested in mathematics, Jessica stated at the beginning of the school year that she was most engaged during physics because, for her, these formulas were "fascinating". On the other hand, she was less interested in mathematics. At the end of the school year, she was completely disengaged from mathematics and her engagement level for physics had also dropped. In the last interview she shared her experience about the last year and stated "I expected physics to be more fun and I find mathematics actually too extensive". She did not find the subject matter, such as analytical geometry, personally relevant any, as she wanted to become a psychologist. Therefore, she was opting to study human sciences.

The drop in Kim's engagement level for mathematics occurred for a similar reason. Her engagement level at the beginning of the year was high. The teacher was trying to prepare her for a challenging mathematical study program. As she described herself as an "overachiever", she was also striving for this. However, she realised by the end of the school year that she just did not enjoy mathematics that much any more, and was considering a study path focused on tourism and languages.

Specific topics covered within the curriculum were of particular importance in Zoé's case. She stated that she was more emotionally engaged during the last iSTEM module about the revalidation tool, as it was more relevant to her than the other modules. In the first interview she clarified that she had chosen a scientific study path because she was interested and enjoyed everything that is related to daily life, "because we constantly come in contact with it". As she found the lessons regarding the revalidation tool to be more related to daily life, she found them more interesting compared to other iSTEM lessons: "We had to learn how to help people, help them to cure. It was also about the forces, looking what really happens during an accident. That's something related to the daily life and something you can apply."

On the other hand, this module was less interesting for Olivia as she did not experience the challenge in this module as "authentic". In the last interview she mentioned:

| | |
|---|---|
| Olivia: | We had to make something for a boy who has been stupid and wasn't wearing his belt [fictive]. He's in a wheelchair and he wants to learn using his hands. So we had to design a revalidation tool for his arm. So then we searched for which muscles he had to train. I said to the teacher "But madam, you can just use little weights for this". And then she said, "Yes actually, but you may not, you may not say that." "Yes, why not?" "Because you need to build something". |
| (Int 2) | |

This experience of an inauthentic context constrained her engagement, but was not critical for her general engagement level, as she indicated that she was still highly emotionally and behaviourally engaged during iSTEM at the end of the year.

### *"Three hours straight making independent exercises is just boring"*

A final factor within the learning environment that was critical for students' engagement in this study was time-related, in the sense that these students claimed that there was too much, or too little, time devoted to a certain topic or activity during the lesson.

Zoé's engagement during the last module of iSTEM was, for example, enabled by the topic, but on the other hand she found that the independent student work took too much time. This made her feel bored and severely constrained her engagement. She stated, "I found the exercises that we had to make on our own less fun and interesting. Sometimes it lasted three hours straight, so that was long."

On the other hand, Kim had the opposite experience of iSTEM at the end of the year. She enjoyed the first module the most, because the students had more time to make everything work compared to the other modules.

For Sarah (School C), a time-related aspect also constrained her engagement in the STEM learning environment. In the interviews she indicated that she was especially highly engaged in mathematics. However she mentioned that she was sometimes bored if she finished all exercises while the other pupils were still busy. She mentioned in both logbooks that this was also the reason that she found some lessons less pleasant. In the second logbook she wrote the following about one of the physics lessons: "We are busy for a long time with the same task and I'm bored in the class because the rest can't follow very well. That counts also for mathematics for sure."

In contrast to Sarah's experience, Bahir and Jessica felt that the mathematics lessons were sometimes going too fast. This also partly constrained their engagement because they could not catch up and this made them to withdraw.

## Discussion

Engaging students in STEM is an important societal need. Therefore, it is important to gain insight into which factors students experience as engaging or constraining for their engagement within diverse STEM learning environments. In this study, we applied a multiple case study in order to understand this issue. We followed ten grade 9 students through one school year, by making use of interviews and logbooks. Both students who followed an integrated STEM curriculum and students who were following a non-integrated STEM curriculum were involved.

First, we investigated how these students' engagement in the STEM learning environment evolved over the course of one school year. Based on the students' self-reported engagement during the interviews, the results show that students' general engagement level regarding the different STEM related courses (iSTEM, mathematics, physics) remained mostly stable during the school year. When changes in students' engagement did occur, students mostly developed towards increased disengagement. This was the case for Kim, Jessica, Max and Bahir. These students indicated that the *subject matter* and how this was related to their personal interests, was a critical factor that was responsible for the change in their engagement. As a consequence, some of these students (Jessica and Kim) were opting for a study path that would be more relevant for the careers to which they aspired, as they experienced the mathematics lessons as neither interesting nor personally relevant by the end of the school year. The fact that the subject matter was so determinative for these students' engagement and lead to different educational aspirations for Kim and Jessica, reflects the fact that individual interest is the most important aspect regarding educational and vocational choices (Hidi, 2006; Renninger, 2015). Aside from this general observation, the STEM subject matter was more specific and extensive for these students, compared to 8th grade, as they chose a curriculum with a focus on STEM. Consequently, this year was very critical for students such as Jessica and Kim. In addition to lesson content, changes in experiences concerning the quality of *relationships with peers and teachers* were determinative for changes in Kim's and Emily's engagement with regard to iSTEM. *The relationship with the teacher* was critical in either constraining or enabling other students' engagement in the STEM learning environment. Especially in School A, the mathematics teacher had a crucial role in enabling participants' engagement during mathematics. On the other hand, the physics teacher in the same school, severely constrained both Kim's and Olivia's engagement. Based on the rich descriptions provided by the participants in School A, in both interviews and the logbooks, we can conclude that the mathematics teacher offered a highly need supportive teaching style, in terms of providing autonomy, relatedness and structure. In contrast, the physics teacher at the beginning of the school year had a more "controlling" motivating style. In addition, the substitute teacher, who replaced the original physics teacher later on during the school year, clearly did not provide sufficient autonomy and structure. These findings, based on students' own observations, confirm earlier research that highlights the importance of the teacher's role, and more specifically, the provision of basic psychological need support, for students' engagement in STEM (Skinner et al., 2017, De Loof et al., 2019). Another critical factor for students' engagement, from the students' perspective, was *collaboration with peers*, a conclusion which aligns with the research of Gasiewski et al. (2012). For all students in our study, this was a factor that enabled their engagement in the STEM learning environment. Importantly, this was the case when students experienced the relationship with their peers during group work as cooperative, and even more so, if they felt a sense of "relatedness" towards them. On the other hand, negative experiences with peers during group work were also a factor that constrained the engagement of some students. This qualitative finding aligns with the model of Skinner et al., which proposes that students' engagement will be fuelled by *supportive* relationships with peers (2017). The current study adds detail to Skinner et al.,'s claims by highlighting that experiences with peers were especially important for participants' engagement during iSTEM. This is not completely surprising, as in this learning environment collaboration between students was very common. More remarkable was the fact that these relationships were, at least for some cases, more crucial than the lesson content itself, or the type of student work. However, regarding the latter, we found that *hands-on activities* enabled most students' engagement, which is in line with the findings of Hampden-Thompson & Bennet (2013). For some cases, these types of activities were also crucial. For example, for the case of Jessica, doing *experiments* during physics was critical in enabling her engagement, while for Bahir and Nathan the *research and design activities* during iSTEM were most important. For Bahir, the experienced freedom and autonomy, compared to the mathematics lessons, was most important. This finding suggests that iSTEM can be a good outlet for students such as Bahir, who feel less comfortable in a teacher-centred learning environment. Consequently the iSTEM learning environment, might keep such students engaged in STEM. On the other hand, we noticed that the freedom experienced during research and design activities could also constrain students' engagements, as was the case for Emily in the beginning of the school year. Another interesting finding concerns the process of trial and error inherent to the research and design activities during iSTEM, with an experience of final success included. We found that this experience could lead to intense emotional engagement and, in the case of Nathan, persistence. Lastly, the results show that *time-related aspects*, such as how much time was devoted to a certain topic or specific student work, can also enable or constrain students engagement.

Interestingly, we did not find evidence that the (non)-integrated nature of the STEM learning environment was a meaningful factor for students' engagement, according to the participants in this study. This is in contrast to earlier results by Struyf et al. (2019) showing that the integration of STEM content was an engaging factor, for at least some students. This was the case when the direct relevance of the subject matter became clearer through its integration and application. However, we found in the current study that participants generally saw the relevance of physics and mathematics in order to solve problems during iSTEM. When the interviewer asked the students who followed the iSTEM curriculum about their perceptions and experiences with regards to the integrated nature of iSTEM, they mostly stated that "you need mathematics/ physics for iSTEM" and found this generally "good". On the other hand, Max, who did not follow the iSTEM curriculum, stated throughout the interview: "You learn a bit of everything, but then I always think: will you need this later? I do not feel like there was one lesson that I really got anything out of." This indicates that he did not see any relevance of mathematics or physics, despite his career aspiration of becoming an engineer. Nevertheless, this stance did not seem to impact his engagement in mathematics as he was highly engaged. It was also not clear from the data if this possibly impacted his engagement with regard to physics.

Although it was not the focus of this study, our results also show that even when students are highly engaged in a certain STEM course, they will not necessarily develop a related “science identity” and accompanying career plans as Skinner et al. (2017) suggest. They define a science identity as *“students’ deeply held views of themselves and their potential to enjoy and succeed in STEM classes and careers”* (Skinner et al., p. 2437). Olivia, for example was highly engaged during iSTEM but mentioned that: “I like working with my hands, but I don’t really see myself becoming an engineer. It seems nice to me that I can make it, to once again make it at home or later. But I can’t imagine it really as a profession.” This finding, confirms the “key dilemma” in science, as Archer et al. (2010) call it, which implies that students can be highly engaged in science, but may still see it as “not for me”. Theoretically, this finding implies that it is important to make a clear distinction between a “STEM learner identity” and a “professional STEM identity”.

### *Implications for practice*

The findings in this study give us more insight into how we can enable students’ engagement, both in integrated and non-integrated STEM learning environments. Generally, the results afford the suggestion that collaborative activities and hands-on activities enable students’ engagement and, thus, are good activities to implement in the STEM learning environment. In this sense, iSTEM education is a good practice as it can facilitate the implementation of such activities. However, these activities imply increased interaction between peers, and the quality of this interaction was found to be most crucial for some students’ engagement. This implies that teachers have a crucial role in managing students’ relationships during group work. Considering that teamwork is an important 21st century skill (Binkley et al., 2012), it might not always be ideal for students to work in self-chosen groups. While doing so enabled some of the students’ engagement in this study, it does not sufficiently prepare students for future experiences on the labour market. However, it might be hard for teachers to get a good and complete overview on how all student groups in the class are functioning. Therefore, a reflection instrument for students in which, after each lesson, they can write about their positive and negative experiences with regard to the group work or the lesson in general, might be a good practice. This might be a tool that enables teachers to notice when problems within student groups are occurring more rapidly and to give students better feedback. Additionally, teachers might, through the use of a reflection instrument, be quicker to notice when students such as Emily need more guidance in student-centred learning environments such as the iSTEM lessons or when pupils experience problems with time-related aspects of the lesson.

With regard to research and design activities during iSTEM, we found that is very important that STEM teachers let students experience the “success feeling” after the trial and error process, as this experience led to strong emotional and behavioural engagement among the students in this study. Moreover, we suggest that it would enable students’ engagement if students could choose between different iSTEM modules with different themes, based on what they find personally interesting and relevant.

Lastly, the results suggest that strong teacher professionalization focused on how teachers can thoroughly fulfil students' basic psychological needs in STEM, is very important (De Loof et al., 2019). Teaching in a student-centred learning environment such as an iSTEM learning environment might be challenging for teachers who lack experience with student-centred teaching. Indeed, their role in a student-centred learning environment as a coach and facilitator, instead of a dispenser of knowledge, becomes more complex. In particular, covering the complete curriculum, while simultaneously balancing the provision of enough autonomy on the one hand and structure on the other hand, might be a challenge. As we earlier suggested, this challenge is an important aspect to focus on during professional development courses for these teachers specifically (Struyf et al., 2019).

### *Study strengths, limitations and future research*

By conducting this study, we contributed to the literature concerning students' engagement in STEM in two different respects. First, it was an added value to use a qualitative approach to study students' engagement in the STEM learning environment, as previous studies that investigated this topic mostly used a quantitative approach. This allowed us to discover which experiences with aspects of the learning environment were most meaningful from students' point of view, with regard to (a) enabling and constraining student engagement and (b) changes in student engagement over the course of one school year. It was, for example, remarkable that relationships with peers and the teacher were generally more meaningful for certain students then the lesson content and the type of student work. Moreover, the qualitative approach allowed us to illustrate how students' engagement manifested itself more specifically in different types of STEM learning environments. There is a distinct lack of research on students' engagement in an integrated STEM learning environment, which is the second strength of this study.

A disadvantage of the interview method we applied is the fact that one participant might be more talkative than the other. We noticed this during interviewing the 9$^{th}$ grade students involved in this study. Nevertheless, we could counter this disadvantage by including closed-ended questions in the interview guide and through the use of logbooks in between the two interviews as a secondary data gathering method. Hence, this disadvantage did not put the validity of our data at risk. A second limitation is that we used only self-report measures to investigate students' engagement. Sinatra et al. (2015), who discuss the challenges of measuring students' engagement in science, point to the fact that self-report measures have the "inherent problem of retrospection". In other words, often these measures ask participants to reflect back to the lesson they just experienced. Based on the measures we used, students were asked to reflect on all lessons of the last trimester, but it is possible that the participants were biased towards reflections on the most recent lessons they experienced. Moreover, students' engagement is not captured "in real time" through such measures. Therefore, it would be of added value if future research investigating (the development of) students' engagement in STEM qualitatively, additionally includes the use of multiple observations as an extra data triangulation method.

Engagement is a very context dependent and fluid concept from the person-in-context perspective we adopted (Sinatra et al., 2015). These characteristics of the concept are illustrated by students in this study who stated that they were, for example, disengaged at certain moments during the lesson or in "some" lessons. We especially aimed to capture (changes in) students' general engagement level and factors that were critical in enabling or constraining student engagement through one complete school year. Future research capturing changes in students' engagement qualitatively will ideally follow up students more intensively, or for a longer time. In addition, such research might also target students who do not have an initial interest in science, as this was the case for the students in this study. Considering that STEM is valuable for all students in our highly technological societies (Bøe et al., 2011), it is also necessary to understand how we can engage this target group in STEM.

## Conclusion

To conclude, we found in this study that several factors were critical for (changes in) students' engagement in diverse STEM learning environments. From the students' point of view these are: collaboration, the quality of relationships with peers and teachers, hands-on activities, subject matter and time-related aspects. The findings suggest that integrated STEM education (iSTEM) is a practice that can engage students in STEM as it facilitates the implementation of collaborative activities with peers and hands-on activities. However, the results show that during these activities in particular the quality of relationships with peers, and teacher's role as a coach is crucial to enable students' engagement. These findings are innovative as, to the best of our knowledge, no other studies have investigated which factors within diverse STEM learning environments, including iSTEM learning environments, are meaningful for (changes in) students' engagement, from the student's perspective.

# CHAPTER 6

# General discussion

## General discussion

The research in this dissertation deepens our understanding of student engagement in Science, Technology, Engineering and Mathematics (STEM) and contextual factors within STEM learning environments that support and facilitate it. In this chapter, we first briefly provide a resumé of the need to examine students' engagement in STEM. Next, we summarize the main findings that can be found across the different studies in this dissertation. We also reflect on its methodological and theoretical contributions and discuss future paths for research. Finally, we discuss the implications for STEM educational practice and conclude with the most important take-away messages.

### *The need for increased understanding of student engagement in STEM*

Over the past decade, a key theme in educational research has been the decline in students' engagement in STEM (Bøe, Henriksen, Lyons & Schreiner, 2011; OECD, 2008a). Several reasons underlie the importance of placing students' declining engagement in STEM high on the research agenda. First, STEM increasingly plays a role in contemporary society, which demands critical and literate citizens who are aware of the role of STEM in society and understand the basic concepts of the different STEM disciplines (Osborne & Collins, 2001; Schreiner, 2006). Second, society needs a larger number of specialized STEM professionals who are, among other things, needed to address complex environmental challenges (NAP, 2018; Nadelson & Seifert, 2017).

Education has an important role in engaging and preparing students in STEM. Consequently, new – in particular student-centred – educational approaches such as the integrated STEM (iSTEM) approach have arisen, in order to strengthen students' engagement and preparation in STEM (Sawada et al., 2002; Nadelson & Seifert, 2017). This new vision(s) of science learning demands for a better conceptual understanding of student engagement in STEM and research that captures the contextual specificity of student engagement in STEM (Schmidt, Rosenberg, & Beymer, 2018).

There is already a great deal of research in conventional STEM learning environments that captures contextual factors that are of importance for students' engagement (e.g. Lavigne, Vallerand, & Miquelon, 2007; Skinner, Saxton, Currie, & Shusterman, 2017). This research (e.g. Lavigne et al., 2007; Skinner et al., 2017), demonstrates the potential of using a Self-Determination Theory approach (SDT) as an analytical lens, to improve our understanding of how students' engagement in STEM learning environments can be fostered. Compared to other motivation theories, SDT offers an interesting alternative perspective to investigate students' engagement in STEM as this theory highlights the vital role of *intrinsic motivation*, common to all students regardless of social background or prior experiences (Skinner et al., 2017). However, to expand on efforts to validate current theoretical propositions – based on SDT – of motivational processes within STEM learning environments, additional data sources, such as qualitative student interviews and classroom observations are needed (Skinner et al., 2017).

Hence, using SDT as an analytical lens, we aimed to build further on existing literature with regard to students' engagement in STEM, by addressing the following research aims:

- Unravel the aspects or 'ingredients' that support and facilitate students' collective and individual engagement within iSTEM learning environments as well as conventional segregated STEM learning environments.

- Gain a deeper insight in how students' engagement occurs in relation to their interactions with others and contextual factors within diverse STEM learning environments.

- Deepen our understanding of motivational processes in STEM learning environments, by investigating the relationships between important motivational concepts.

## Main outcomes

We summarize the results of the first study in this dissertation in the first section, as this study approached engagement from a STEM identity perspective, which differed from the other studies. Then, we summarize the results of the final three studies in the second section.

### *The exploration of the social and societal interest gap*

The focus of study 1 was related to students' STEM identity. The starting point of this study was the fact that (Flemish) students who do not pursue hard science study at the university level *(NHS-choosers)* have more interest in 'working with people' *(social orientation)* and 'serving or helping others' *(societal orientation),* compared to their counterparts who choose to study hard science *(HS-choosers)* (Boeve-de Pauw, Van Petegem, & Lauwers, 2014). To explore this interest gap, we conducted six focus groups with a total of 58 Flemish grade 12 students, to investigate if they had clear and nuanced perceptions about science careers' social and societal orientation. Furthermore, we explored students' social and societal interests.

The findings in this study showed that Flemish grade 12 students had unclear perceptions about hard science careers' *social* orientation. These students perceived hard science careers as 'isolated', while collaboration with others is in fact an important part of daily reality for most hard science professionals nowadays. This finding is in line with earlier qualitative research that found stereotypical views about STEM professions among the student population (Clarke & Teague, 1996; Cleaves, 2005; Holmegaard, Madsen, & Ulriksen, 2014). Moreover, the results in our study suggest that these perceptions may lead students who have strong social interests away from such careers, as they cannot identify with them. However, most grade 12 students had more accurate and realistic perceptions with regard to hard science careers' social orientation. This was especially apparent for students in the industrial sciences track, who had already gained experience with the social orientation of STEM practice and who could express the necessity of hard science careers' social orientation well. Students who followed the curriculum 'science and mathematics' stated they had only recently gained a better view of hard science professionals due to information sessions with regard to study choice.

Students' beliefs about hard science careers' *societal* orientation were mostly positive, in the sense that they believed that these professions create progress for society. Nevertheless, only a few students in our research mentioned the role of hard science careers in combating social and ecological problems. These findings support earlier research of Osborne and Collins (2001) who conducted focus groups with 16-year-old pupils in London about their views of the role and value of science education. Students in the latter research expressed the general value of science in society, often illustrated with examples of its instrumental value (e.g. the use of washing machines).

Regarding students' social and societal interest, we found that NHS-choosers often mentioned social and societal interests as an important vocational interest, while HS-choosers mentioned other interests, such as practical interests. HS-choosers did not express the view that they found this interest unimportant, but expressed it more as something self-evident. Interestingly, we also found in this study that students expressed a very specific 'direct' (e.g. a doctor who helps his patients) or 'indirect' societal interest (e.g. developing new medicines). This finding implies that students with a 'direct' societal interest will be probably less likely to pursue a hard science career.

### *Contextual factors that matter in STEM learning environments*

The focus of the second and third study was to investigate specific contextual factors in STEM learning environments that are significant to create a motivational atmosphere supporting grade nine students' collective classroom engagement. In both studies, we conducted classroom observations in iSTEM and conventional 'segregated' STEM learning environments. In addition, we used an online questionnaire in the second study to assess students' motivation. In the third study, we conducted focus groups as additional data source.

In the fourth study, we took a different approach to study students' engagement in STEM. In contrast to study 2 and 3, which investigated students' collective engagement, we focused on students' *individual* engagement. We examined how students' engagement changes over time, and which contextual factors in STEM learning environments are most meaningful for (changes in) students' individual engagement, from the student's point of view. For the purpose of this latter study, we conducted a multiple case study and followed ten grade nine students over the course of one complete academic year. Both students who followed an iSTEM curriculum and students who followed a traditional STEM curriculum were included. We collected data through interviews and logbooks.

Based on the various findings in these studies, we summarize below the specific contextual factors within STEM learning environments that have been found to be most crucial to support and facilitate students' engagement: (1) the importance of teachers' guided autonomy, (2) the degree of student-centredness in the learning environment.

*The importance of teachers' guided autonomy*

The results of the second study show the significance of teachers' provision of autonomy and structure during instruction for students' classroom engagement in both iSTEM and conventional STEM learning environments. These results confirm earlier research that highlighted the importance of teachers' basic psychological need support in a conventional 'segregated' STEM educational context (e.g. Black & Deci, 2000; Hofferber, Basten, Großmann, & Wilde, 2016; Lavigne, Vallerand, & Miquelon, 2007; Valås, H. & Søvik, N., 1994). Surprisingly, no relation was found between teachers' involvement, which is assumed to fulfil students' need of relatedness (Reeve, 2012) and students' engagement.

The results of the qualitative data in the third and fourth study also show that students who experienced autonomy in STEM learning environments expressed more emotional engagement, such as interest and enjoyment. However, these studies made clear that exclusive provision of autonomy in the STEM learning environment is not sufficient to facilitate students' engagement. Also, the teacher's role as guide is crucial. Students who experienced autonomy but not sufficient guidance expressed *disaffection*. Feelings of frustration, being 'overwhelmed' and emotional and behavioural withdrawal were common in these students. These findings are in line with Brush and Saye (2000) who found similar results in a study evaluating the implementation of a technology-enhanced student-centred unit. Their results showed that students felt lost or overwhelmed when the teacher did not provide enough structure, by acting as a non-participant observer in the classroom instead of a resource and coach for students.

*Student-centred STEM learning environments matter, but …*

Based on the observations and focus groups in the third study, we found that student-centred STEM learning environments support and facilitate students' collective classroom engagement. This is in line with earlier research that investigated the role of student-centred STEM learning environments for students' engagement (Gasiewski et al., 2012; Hampden-Thompson & Bennett, 2013; Wu & Huang, 2007).

Additionally, we found, in the third study, that an iSTEM approach facilitates the implementation of a student-centred STEM learning environment. Based on the qualitative data in the fourth study, we found that the *research and design activities* during iSTEM lessons were an important factor for certain students' engagement in STEM. Also, *collaborative activities*, both in iSTEM and conventional learning environments, facilitated participants' engagement. However, this was only the case if the students experienced that the relationships with their team members were supportive. Certain students experienced their relationships with peers as non-supportive during iSTEM lessons and this constrained their engagement crucially. Furthermore, experiencing a lack of teacher's guidance and autonomy support were, for certain students, most crucial for their engagement in the iSTEM (and conventional) learning environment. Other factors that were found to be crucial for students' engagement in (the iSTEM) learning environment, from the students' point of view were the topic of the learning content and time-related factors (e.g. too much or too little time devoted to a certain topic or activity during the lesson).

## Theoretical and methodological contributions

In this section, we reflect on the theoretical and methodological contributions of this dissertation and explore paths for future research. To this end, we use the *self-determination* model of motivational processes in STEM classes (Skinner et al., 2017) as an analytical lens (see Figure 1). We structure this section in accordance with the three different conceptual approaches we used to investigate student engagement. Finally, we propose, based on the insights we gained from this dissertation, an adapted version of this model (see Figure 2).

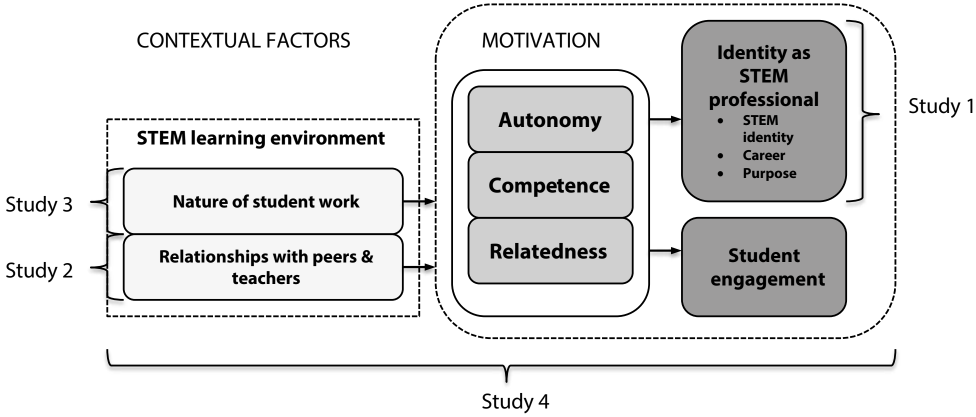



**Figure 1:** A self-determination theoretical model of motivational processes in STEM classes (based on Skinner et al., 2017)

### *Collective engagement*

In the second and third study, we applied a *context-oriented* approach (Sinatra et al., 2015) to investigate students' *collective* engagement in STEM. As such, the focus was on capturing characteristics in the social context (the STEM learning environment) and how these afford or impede engagement (Sinatra et al., 2015). The findings in these studies are valuable as they improved our understanding of which specific factors in STEM learning environments can create a motivational 'cocktail' or atmosphere that supports students' classroom engagement. Based on observational data, we confirmed, in line with Skinner et al. (2017), that *teachers' basic psychological need support* and *the nature of student work* indeed do matter to create such a context. Consequently, these findings strengthen the SDT theoretical model of motivational processes in STEM classes. They also contribute to the literature by grasping a more fine-grained understanding of the contextual factors that also matter in iSTEM learning environments in particular. Moreover, we improved our understanding of how students' engagement occurs in relation to these contextual factors, based on the focus group data in the third study.

With regard to the nature of student work, we argue that iSTEM education has the potential to fuel students' engagement as it might provide – in contrast to conventional 'segregated' STEM education – more room to fulfil students' need for autonomy and relatedness due to its student-centred nature (e.g. based on cooperative learning, problem-centred learning). Our findings indeed suggest that student-centred learning environments support students' engagement and that iSTEM facilitates the implementation of a student-centred approach. However, we did not investigate whether students' need for autonomy and relatedness was, effectively, more fulfilled during iSTEM, compared to conventional STEM learning environments. Thus, this is an interesting line for further research.

Another important next step for research is investigating the significance of the iSTEM approach for engagement of diverse student groups (e.g. based on difference(s) in gender, achievement or degree and quality of motivation). Future research can therefore measure students' individual engagement in iSTEM and conventional STEM learning environments at the individual level (e.g. based on self-report questionnaires). Thus, future research can investigate if iSTEM or conventional STEM is, for example, more beneficial for certain student groups than others. As an iSTEM learning environment generally requires different skills and competences compared to conventional segregated STEM, it might be that high and low achievers, for example, experience different feelings of competence, which in turn will affect their engagement. Moreover, measuring students' individual engagement in iSTEM and conventional STEM would allow us to understand if following an iSTEM curriculum affects students' engagement in the segregated STEM lessons (e.g. mathematics, physics). We noticed that for some students the relevance of the segregated STEM disciplines became clearer in iSTEM. Whether this also positively affects students' engagement in the discipline-based STEM lessons needs to be investigated.

Additionally, we would like to underscore the need for longitudinal research to examine the significance of an iSTEM approach for students' long-term engagement in STEM. In particular, the crucial transition point from secondary to tertiary education needs to be taken into account.

### *Individual engagement*

In the fourth study, we approached engagement from a *person-in-context* perspective (Sinatra et al., 2015) by applying a multiple case study. Because we followed only a few grade nine students throughout one complete school year in a qualitative way, we gained a better conceptual understanding of student engagement in STEM and the contextual specificity of it. We were able to capture general (changes in) engagement levels for different courses and could relate this to various contextual factors, including the factors that we found to be significant for students' collective engagement. On the other hand, the qualitative results also showed us a rather 'momentary' state of engagement that was related to very specific tasks or moments during STEM lessons. This momentary nature of students' engagement in STEM learning environments still requires more research. Observational data would be especially interesting here. Instead of focusing on the teacher's role or the general motivational atmosphere, it would be very important to capture students' conversations and interactions in relation to the ongoing learning environment. We would suggest careful focus on just a few students in this case.

### *STEM identity*

In the first study, we approached engagement from a STEM identity perspective. Briefly, Skinner et al. (2017 p. 2437) defined students' STEM identity as '*students' deeply held views of themselves and their potential to enjoy and succeed in STEM classes and careers'*. We argue, in the first study, that the more students can identify with the nature of student work in STEM and the work of STEM professionals, the more engaged they will be in the STEM learning environment, which in turn will lead to more potential long-term engagement in STEM education and careers. Using SDT as an analytical lens gives more insight into this 'identity process'. Indeed, SDT states that a more autonomous type of motivation[8] will apply to an individual if there is congruence between that individual's personal values and the behaviour that individual expresses (Ryan & Deci, 2000; Soenens & Vansteenkiste, 2011). This, in turn, is assumed to lead to higher emotional and behavioural engagement. Considering the focus of the first study, a student who, for example, values working with people will be more likely to enjoy a STEM class and pursue a STEM career if she perceives the nature of STEM work as socially oriented.

Importantly, this assumption implies a different relationship between students' engagement and students' STEM identity than proposed by Skinner et al. (2017). These authors proposed an opposite relationship, as they argued that engaged students will, over time, *'cement a valuable internal motivational resource, namely, a strong identity as a scientist – which combines a personal science identity with future plans for a career involving science and a sense that science serves important societal purposes'* (2017, p. 2437-2438) through their active engagement, persistence and success in STEM classes. In addition, we found evidence in study 4 that even when students are highly engaged in a certain STEM course they will not necessarily develop a 'related 'science identity' and accompanying career plans. Therefore, we suggest a different theoretical relationship between students' engagement in STEM and students' STEM identity. We represent them in Figure 2 as two motivational concepts that might, but not necessarily, mutually reinforce each other. Moreover, we suggest that it would be valuable to theoretically make a distinction between a 'STEM learner identity' and a 'professional STEM identity', as both concepts do not necessarily overlap.

We also gained more insight in this dissertation into what the concept '*societal orientation'* or *'purpose'* – as put forward by Skinner et al. (2017) – implies for the concept STEM identity. Skinner et al. (2017) suggested that '*a sense that STEM serves important societal purposes'* makes part of a strong STEM identity. However, based on the focus group data in the first study, we found that 'serving important societal purposes' is not necessarily an aspect that is important to all students. As such, we believe that this 'societal' aspect should not be theoretically put forward as a crucial component of a (strong) STEM identity because this is rather an individual's personal interest or value. In fact, students who pursued a hard STEM career and, thus, can be considered as students with a strong STEM identity, mentioned that they rather valued other (e.g. practical oriented) interests.

8 See chapter 2 - Figure 1 "the motivation continuum" - for a complete overview and explanation of different types of motivation.

With regard to future research concerning students' STEM identity, we underscore the need for more research on students' diverse perceptions concerning STEM professions. In particular, we need to explore if new educational approaches such as iSTEM can improve students' perceptions about the diversity and nature of STEM careers. Indeed, more accurate perceptions will help individual students to make a well-considered study choice, fitting their identity and personal interests.

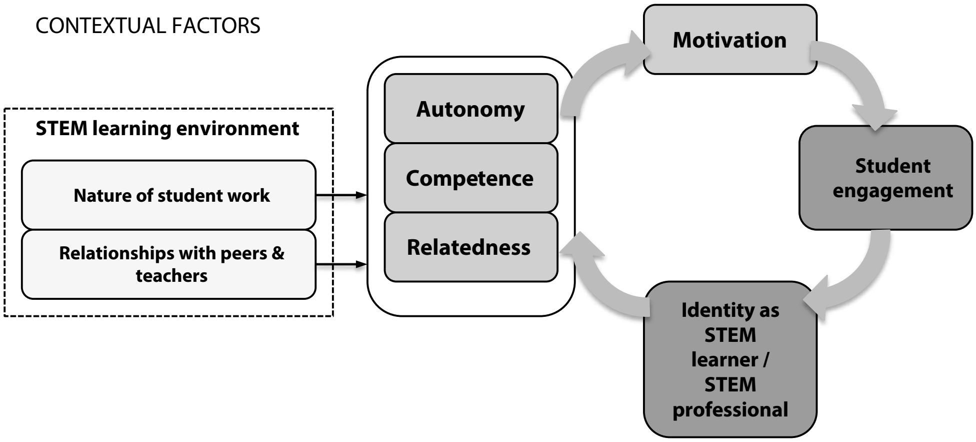



**Figure 2:** Adapted version of self-determination theoretical model of motivational processes in STEM classes (based on Skinner et al., 2017 & own results in studies 1 through 4)

In summary, the findings throughout the different chapters allowed us to make a new theoretical proposition, based on the SDT model of motivational processes in STEM classes (Skinner et al., 2017). Naturally, the suggested relationships between the motivational concepts need to be further explored and validated in future research.

## Implications and suggestions for practice

The key findings of this dissertation enable us to formulate several implications for practice. We first focus on the main implications for STEM educational practice in general. Thereafter, we reflect in greater depth on the practice of iSTEM education.

First, we suggest, based on the findings in the first study, that creating more accurate perceptions about hard science careers' social and societal orientation is a good practice. This could be especially beneficial in order to engage students who have high social and societal interests, who are often female (Morgan et al., 2001). We suggest that one strategy to accomplish this is implementing (hard) science programmes that apply relevant social and societal activities in science. Another method is inviting diverse STEM professionals to schools to explain and show students their daily work practices.

Second, we emphasize, in line with Kirschner, Sweller and Clark (2006), the necessity of teacher's guidance throughout students' learning processes. In addition, we highlight that the combination of providing autonomy and structure is especially important in order to engage students in STEM learning environments. Adler, Schwartz, Madjar and Zion (2018) referred to this as *'guided autonomy'* support. However, balancing autonomy support and structure during instruction in diverse STEM learning environments might be a challenge for teachers. An iSTEM learning environment, for example, incorporates automatically more elements to support students' feelings of autonomy and relatedness through the required student-centred approach (e.g. problem-centred learning, cooperative learning). Balancing this autonomy-supportive learning environment with sufficient structure might be a challenge. On the other hand, bringing structure into a teacher-centred learning environment (e.g. lectures) might be easier, while it could be more difficult to support students' need for autonomy and relatedness in this learning environment. Considering the importance of teachers' motivating style in STEM, professional development programmes could especially focus on how teachers can provide and balance sufficient autonomy and structure in diverse STEM learning environments. Based on the findings in the fourth study, we suggest, for example, that it is very important that teachers let students experience the 'success feeling' after the trial and error process during research and design activities in the iSTEM lessons, to optimize students' engagement. On the other hand, providing sufficient guidance when students are 'stuck' during this process is also necessary to maintain students' engagement.

Finally, we suggest that implementing student-centred learning environments is a good educational practice. In such an environment, it is important that the ideas that students bring to the classroom are acknowledged and respected. Therefore, teachers will need to take on a role as 'coach', encouraging students' active participation through 'hands-on' and 'minds-on' activities, and stimulating students to find more than one solution for a problem (Sawada et al., 2002). However, especially in these student-centred learning environments, we should be cautious about students' relationships with peers and the teacher because more interactions take place. We suggest that a reflection instrument for students could be a good instrument for teachers to capture students' needs in student-centred STEM learning environments and give personalized feedback. Additionally, we highlight, in line with Baeten et al. (2013), that gradually moving from a teacher-centred to a student-centred approach can be important. Across the qualitative data in the third and fourth study, we noticed that the student-centred approach during iSTEM was a new experience for some grade nine students. For these students, it is important to have sufficient time in order to adapt themselves to their more active and 'critical' student role, in order to maintain their engagement. Also, for teachers who lack experience with student-centred teaching, the strategy of slowly adapting the instructional approach could be beneficial.

### *iSTEM (@School) as good practice to engage students in STEM?*

In the introduction of this dissertation, we hypothesized that iSTEM education has potential to increase students' engagement in STEM, through its student-centred and integrated nature. The quantitative results in the third study partly confirmed this hypothesis. Based on the observational data, we found evidence that students' collective engagement in iSTEM was higher than students' collective engagement in conventional 'segregated' STEM learning environments. However, further investigation made it clear that the student-centred nature of iSTEM learning environments was, in particular, of importance for students' engagement, rather than the integrated nature.

These quantitative findings gave us general insight about which role iSTEM education can play for students' collective engagement. The qualitative data in the third and fourth study gave us additional insight into the contextual factors within iSTEM learning environments that are mostly important from students' points of view. Based on these qualitative findings, we further reflect on iSTEM as an educational practice, in line with the five key principles formulated by iSTEM@School.

*The integration of STEM content*

Based on our quantitative findings, we did not find evidence that the integrated nature of iSTEM supported students' engagement. However, our qualitative data showed a different picture. Based on the findings of the third study, it became clear that the integrated nature of iSTEM can support some students' engagement, if it makes the (in)direct relevance of the STEM content clearer for students, through the integration and application of STEM content. In the fourth study, we did not find evidence for this, but also fewer students participated in this study. We suggest, based on these findings, that it is not a very significant factor for most students' engagement, but that the integrated nature might facilitate certain students' engagement.

*Problem-centred learning*

We assumed that relating the STEM learning content to authentic real-world problems could facilitate students' engagement, as it can increase the relevance of this STEM learning content. The qualitative data in the third and fourth study offer evidence for this. However, we found that it is important that students experience the problem as personally relevant and closely related to problems in the 'real world'. As this is very person dependant, we suggest that students' engagement in STEM could be supported if they can choose to work on a challenge that is personally relevant to them.

The learning modules developed by iSTEM@School, especially the module regarding the revalidation tool, could be interesting for socially and societally interested students. Learning modules that focus on a genuine (not fictious) real-world problem (e.g. real research and design challenges faced by companies) could possibly be even more interesting for students who are highly societally oriented. However, research to investigate these latter hypotheses is needed.

*Inquiry-based learning*

Regarding the key principle of 'inquiry-based learning', our results show that teachers' guidance is crucial. Students who are not used to looking up information independently and conducting experiments can feel overwhelmed when they experience a lack of help. We refer in this context again to the importance of teachers' guided autonomy in order to optimally support students' engagement.

*Design-based learning*

The qualitative data in this dissertation showed that research and design activities were a factor within the learning environment that enabled nearly all participants' engagement. In particular, the experience of 'freedom', in terms of not having 'to sit still', was experienced by most students as an engaging factor. Also brainstorming about the design and making their own choices with regard to design were mentioned in the qualitative research as positive aspects that related to students' engagement. Moreover, we found that the process of trial and error inherent to these activities, with a final experience of success, can also be significant to support students' engagement. Thus, we suggest that research and design activities are a good method to support students' engagement in STEM, as these activities can fulfil students' feelings of autonomy and competence.

*Cooperative learning*

According to SDT, we hypothesised that cooperation with peers in the STEM learning environment might fulfil students' need for relatedness and, in turn, students' engagement. Based on the qualitative findings in the third and fourth study, we indeed found that students experienced collaboration with peers as an engaging learning activity. However, the results in the fourth study revealed that, in particular, the experience of support and feelings of 'relatedness' towards peers are crucial to facilitate students' engagement during collaborative activities. This finding implies that it is effective to let students work in teams to support students' engagement, but that teachers have an important task to follow up the relationships in student teams. To improve the relationships between group members, we stress, in line with other authors, the importance of stimulating students' teamwork skills (Guzey, Moore, Harwell, & Moreno, 2016) and communication skills (Bryan, Moore, Johnson & Roehrig, 2015; Stohlmann, Moore, McClelland, & Roehrig, 2011; Thibaut et al., 2018a).

We also argue that positive interdependence needs to be stimulated (Ashgar, Ellington, Rice, Johnson, & Prime, 2012; Thibaut et al., 2018a). Positive interdependence refers to the perception that we are linked with others in a way so that we cannot succeed unless they do, or as Johnson and Johnson (1999, p. 71) state; 'their work benefits us and our work benefits them'. According to these authors, positive interdependence must be established through mutual learning goals (e.g. learn the assigned material and make sure that all members of your group learn the assigned material). Strategies to strengthen positive interdependence are the use of (1) joint rewards (e.g. if all members of your group score 90 percent correct or better on the test, each will receive 5 bonus points), (2) divided resources (e.g. each group member receives a part of the information to complete the task), and (3) complementary roles (Johnson & Johnson, 1999).

In summary, we can conclude that iSTEM is in general a good practice to support students' engagement because of its student-centred nature. These results are important, as previous research has found that engagement leads to other positive student outcomes, such as academic learning, achievement, skill development and academic resilience (Reeve, 2012; Skinner et al., 2008). However, in line with Nadelson and Seifert (2017), we highlight the importance of good implementation of iSTEM education and teachers' professional mind-set. In this dissertation, we found that it is especially important that teachers adopt a professional mind-set as 'coach' during instruction, providing students with 'guided autonomy'. We also need to be cautious that teachers do not hold too high expectations of students who follow an iSTEM curriculum, as we noticed in the data that this could lead to students' disengagement. Nadelson and Seifert (2017), in this regard, stated that it is critical to the success of iSTEM education that the complexity of the iSTEM context is aligned with students' knowledge level.

## Take-away messages

» Based on using Self-Determination Theory (SDT) as analytical lens and applying a rich pallet of research methods, we gained a rich understanding of student engagement in STEM and significant contextual factors in the STEM learning environment that support it.

» SDT offers a valuable analytical lens to improve our understanding of how student engagement in STEM can be strengthened, as it highlights the vital role of *intrinsic motivation*, common to all students.

» In line with other research, we found that there are two significant contextual factors in the learning environment that can create a positive motivational atmosphere supporting students' classroom engagement in STEM, namely; (1) teachers' motivating style in terms of high basic psychological need support (autonomy and structure) and (2) the learning environments' student-centredness.

» Importantly, we found that integrated STEM (iSTEM) education facilitates the implementation of a student-centred learning environment, but especially in this learning environment, the teacher's guidance and quality of relationships with peers are crucial.

» Highlighting the social and societal components of STEM practice is valuable to create nuanced perceptions of STEM careers and has potential to engage especially students with high social and societal interests.

» Strong teacher professionalization programs are needed, focusing on how teachers can provide and balance sufficient autonomy and structure in divers STEM learning environments.

» In particular, more research in iSTEM learning environments is necessary with regard to (1) divers student groups' engagement, and (2) students' perceptions about STEM professions.

# CHAPTER 7

# Dutch summary

Een thema dat het afgelopen decennium veel aandacht kreeg binnen onderwijskundig onderzoek is het gebrek aan interesse en betrokkenheid van studenten ten aanzien van STEM (Science, Technology, Engineering, Mathematics) (Bøe, Henriksen, Lyons & Schreiner, 2011; OECD, 2008a). Het gebrek aan interesse en betrokkenheid tegenover STEM is problematisch, aangezien STEM een steeds belangrijkere rol speelt in onze samenleving. Dit vereist kritische en `STEM-geletterde` burgers die de basisconcepten van de verschillende STEM disciplines goed begrijpen en beheersen (Osborne & Collins, 2001; Schreiner, 2006). Daarnaast heeft de samenleving nood aan meer gespecialiseerde STEM-professionals die onder andere aan oplossingen kunnen werken voor het aanpakken van complexe milieuproblematieken (NAP, 2018; Nadelson & Seifert, 2017).

Onderwijs vervult een sleutelrol wat betreft het engageren en voorbereiden van studenten in STEM. Vanuit deze optiek ontstonden er de laatste jaren nieuwe – meer studentgerichte – onderwijsbenaderingen zoals geïntegreerd STEM onderwijs (iSTEM) (Sawada et al., 2002; Nadelson & Seifert, 2017). Het vertrekpunt bij een geïntegreerd STEM-curriculum bestaat erin de leerlingen uit te dagen een authentiek, `levensecht` complex probleem op te lossen. Om dit te kunnen waarmaken zullen leerlingen een beroep moeten doen op kennis en vaardigheden uit verschillende STEM-disciplines (Nadelson & seifert, 2017). In tegenstelling tot een eerder traditionele STEM leeromgeving, vereist de iSTEM benadering een studentgerichte leeromgeving. Het doel van zulke nieuwe onderwijsbenaderingen zoals iSTEM is het optimaal voorbereiden van leerlingen op STEM, maar ook het verhogen van hun betrokkenheid of *engagement*.

Deze nieuwe visies op hoe STEM best onderwezen en geleerd wordt, vraagt om een beter begrip van het concept *engagement* van studenten bij STEM. Ook is er onderzoek nodig dat de contextuele specificiteit van studentenbetrokkenheid in STEM vastlegt (Schmidt, Rosenberg, & Beymer, 2018). Dit kan ons onder andere helpen om contextuele factoren te onderscheiden die van optimaal belang zijn om het engagement van leerlingen binnen diverse STEM leeromgevingen te verhogen. Een hoger engagement van leerlingen in de STEM leeromgeving zal op lange termijn op zijn beurt zorgen voor een betere doorstroom naar STEM onderwijs en STEM beroepen.

Vanuit deze probleemstelling waren de drie onderzoeksdoelen in dit proefschrift de volgende:

- Het ontrafelen van de aspecten of 'ingrediënten' binnen iSTEM- en conventionele STEM leeromgevingen die het engagement van studenten bevorderen en faciliteren.

- Een dieper inzicht krijgen in het engagement van studenten in relatie tot hun interacties met anderen en contextuele factoren binnen verschillende STEM-leeromgevingen.

- Inzicht verwerven in motivatieprocessen binnen STEM leeromgevingen door de relaties tussen belangrijke motivationele concepten te onderzoeken.

Om tegemoet te komen aan deze onderzoeksdoelen hebben we in dit proefschrift voornamelijk een beroep gedaan op kwalitatieve en mixed-method dataverzamelingsmethoden. Als analytische lens gebruikten we de Zelf-Determinatie Theorie (ZDT) als overkoepelend theoretisch kader. Deze theorie benadrukt de vitale rol van *intrinsieke motivatie* die inherent is aan alle individuen ongeacht afkomst of eerder opgedane ervaringen (Ryan & Deci, 2000; Skinner, Saxton, Currie, & Shusterman, 2017). In totaal voerden we vier verschillende studies uit, waarin we de onderzoeksdoelen in dit proefschrift telkens vanuit een andere invalshoek benaderden.

De focus van de eerste studie betreft het engagement van studenten in relatie tot hun STEM identiteit. Het uitgangspunt in deze studie is dat (Vlaamse) studenten die geen harde wetenschappen (technologie, ingenieurswetenschappen, wiskunde of fysica) studeren in het hoger onderwijs meer interesse hebben om met mensen te werken (sociale oriëntatie) en anderen te helpen (maatschappelijke oriëntatie), in vergelijking met medestudenten die hier wel voor kiezen. Om deze interessekloof te onderzoeken voerden we een onderzoek uit op basis van 6 focusgroepen met in totaal 58 Vlaamse studenten uit het zesde jaar middelbaar onderwijs. Het doel was om te onderzoeken of deze studenten duidelijke en genuanceerde percepties hadden over de sociale en maatschappelijke oriëntatie van harde STEM beroepen. Daarnaast onderzochten we de sociale en maatschappelijke interesses van deze studenten. De resultaten toonden aan dat een aantal studenten in de focusgroepen stereotiepe opvattingen hadden en geloofden dat dit soort beroepen erg 'geïsoleerd' zijn. De meeste van deze studenten hadden echter meer genuanceerde en realistische percepties omtrent de sociale en maatschappelijke oriëntatie van harde STEM beroepen, wat in lijn ligt met eerder onderzoek. Bovendien toonde deze studie aan dat studenten die er niet voor kozen om harde STEM verder te studeren, meer belang hechtten aan sociale en maatschappelijke aspecten in hun toekomstige carrière. Hun tegenhangers daarentegen vonden deze aspecten niet onbelangrijk maar eerder vanzelfsprekend. Ook vonden we in de resultaten terug dat studenten sociale oriëntatie enerzijds en maatschappelijke oriëntatie anderzijds onderscheidden en ook een heel specifieke interesse kunnen tonen in het 'direct' of 'indirect' helpen van anderen.

In de tweede studie onderzochten we het belang van de rol van de leerkracht voor de motivatie en het *collectieve* klasengagement van leerlingen binnen verschillende STEM-leeromgevingen. Meer specifiek onderzochten we het belang van de leerkracht zijn/haar ondersteuning van studenten hun psychologische basisbehoeften (autonomie, betrokkenheid, competentie). Om de motivatiestijl van leerkrachten en het engagement van studenten te beoordelen deden we 30 klasobservaties in verschillende STEM-lessen (fysica, wiskunde, engineering en iSTEM) in het 3$^{e}$ jaar secundair onderwijs. De motivatie van de geobserveerde studenten werd aan het einde van het schooljaar bevraagd aan de hand van een online vragenlijst. De resultaten in deze studie tonen het belang aan van de motivatiestijl van de leerkracht binnen de context van STEM-onderwijs. Vooral het aanbieden van structuur door de leerkracht blijkt van belang te zijn om zowel het engagement binnen de klas als de motivatie voor het volgen van STEM te verhogen bij leerlingen. Ook de autonomieondersteuning van de leerkracht voorspelt een hoger engagement binnen de klas. Met betrekking tot het verband tussen motivatie en engagement werd er een negatieve relatie gevonden tussen gecontroleerde motivatie en engagement.

In de derde studie hebben we ons specifiek gericht op de invloed van de aard van het studentenwerk in diverse STEM leeromgevingen. Hierbij wilden we het belang nagaan van iSTEM en het belang van een studentgerichte leeromgeving voor het collectieve engagement van studenten binnen de klas. We analyseerden 24 video opnames van klasobservaties in de iSTEM-leeromgeving en conventionele STEM-leeromgevingen (fyscia en wiskunde). Daarnaast deden we zeven focusgroepen met 67 leerlingen uit het derde middelbaar. Uit de resultaten komt naar voor dat leerlingen uit het 3$^{e}$ jaar secundair onderwijs zowel meer emotioneel als gedragsmatig engagement vertonen in STEM-leeromgevingen die een hogere mate van studentgerichtheid omvatten. De belangrijkste bevinding is dat het toepassen van een iSTEM benadering een goede manier is om het engagement van leerlingen in de STEM-leeromgeving te bevorderen omdat het studentgericht lesgeven faciliteert.

In tegenstelling tot de tweede en derde studie hebben we het engagement van studenten in de STEM leeromgeving vanuit een andere invalshoek benaderd en bestudeerd in de vierde studie. In deze studie hebben we ons gefocust op de *individuele* betrokkenheid van studenten en benaderden we dit concept eerder vanuit een holistisch perspectief. Hiervoor voerden we een case study uit waarbij we tien leerlingen uit het 3$^{e}$ jaar secundair onderwijs opvolgden gedurende een volledig schooljaar. Hierbij volgden we zowel leerlingen op die een traditioneel STEM curriculum volgden als leerlingen die een iSTEM curriculum volgden. We verzamelden data aan de hand van interviews en logboeken. De resultaten tonen aan dat verschillende factoren van cruciaal belang waren voor (veranderingen in) het engagement van studenten in diverse STEM-leeromgevingen. Vanuit het oogpunt van de studenten zijn dit volgende aspecten: samenwerking, de kwaliteit van relaties met klasgenoten en leerkrachten, interactieve/ praktijk-georiënteerde activiteiten, de inhoud van de leerstof en tijd gerelateerde aspecten. Deze bevindingen suggereren dat iSTEM-onderwijs een praktijk is die studenten kan betrekken bij STEM, aangezien het de implementatie van groepswerk en het uitvoeren van praktijk-georiënteerde activiteiten faciliteert. Uit de resultaten blijkt echter dat tijdens deze activiteiten in het bijzonder de kwaliteit van relaties met klasgenoten en de rol van de leerkracht als coach van cruciaal belang zijn voor het engagement van de leerlingen.

De resultaten in deze studies zijn vernieuwend en dragen bij aan literatuur met betrekking tot het engagement van studenten in STEM. De belangrijkste theoretische en praktische implicaties van deze onderzoeksresultaten zijn kort samengevat onder de volgende 'take-away messages':

» Aan de hand van de Zelf-Determinatietheorie (ZDT) als analytische lens en het toepassen van een rijk pallet van onderzoeksmethoden kregen we in dit proefschrift een goed inzicht in het engagement van studenten tegenover STEM en belangrijke contextuele factoren in de STEM-leeromgeving die dit kunnen versterken.

» ZDT is waardevol om te gebruiken als analytische lens om ons inzicht te verbeteren in hoe we studenten hun engagement tegenover STEM kunnen versterken, omdat het de vitale rol van intrinsieke motivatie benadrukt die inherent aanwezig is in alle studenten.

» In overeenstemming met ander onderzoek hebben we geconstateerd dat er twee belangrijke contextuele factoren in de STEM leeromgeving zijn die een positieve motiverende sfeer kunnen creëren in de klas, namelijk: (1) de motivatiestijl van de leerkracht in termen van de ondersteuning van psychologische basisbehoeften (autonomie en structuur) en (2) een studentgerichte leeromgeving.

» Een belangrijke constatatie is dat geïntegreerd STEM onderwijs (iSTEM) de implementatie van een studentgerichte leeromgeving faciliteert, maar vooral in deze leeromgeving zijn de begeleiding van de leerkracht en de kwaliteit van relaties met peers van cruciaal belang.

» Het benadrukken van de sociale en maatschappelijke aspecten binnen STEM is waardevol om genuanceerde percepties van STEM-carrières te creëren bij studenten en heeft het potentieel om vooral studenten te engageren die veel belang hechten aan deze sociale en maatschappelijke componenten.

» Het is noodzakelijk om ondersteuning te voorzien voor de professionalisering van STEM leerkrachten, waarbij de nadruk ligt op hoe leraren voldoende autonomie en structuur kunnen bieden in diverse STEM-leeromgevingen en hoe zij deze twee optimaal in evenwicht met elkaar kunnen brengen.

» Meer onderzoek binnen iSTEM-leeromgevingen in het bijzonder is noodzakelijk met betrekking tot (1) het engagement van diverse groepen leerlingen (2) de percepties die leerlingen hebben van STEM-beroepen

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