Research report master project

How do high school teachers influence STEM pipeline leakage? An in-depth qualitative study

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Abstract

The shortage of professionals in the STEM sector has sparked many studies on the factors influencing high school students' educational choices. What causes these students to discontinue the STEM educational career and "leak out of the STEM pipeline"? The present study investigates one – less-researched – factor in particular: the role of teachers in the decision-making process of Dutch students at the moment of their subject cluster choice in the ninth grade and their subsequent study choice. To this purpose, in-depth semi-structured interviews are conducted with twelve randomly selected first-year tertiary students from a university in the Netherlands. These students reported that influencing factors, such as whether a student is interested or talented in the STEM subject, are more important than their attitude towards the STEM teacher. However, when students already have an interest and/or talent for STEM subjects, the STEM teacher is repeatedly reported to catalyse their educational choice. For this reason, this study suggests that to stimulate those students who initially show talent and interest in STEM might be the most effective action for STEM teachers to counteract STEM pipeline leakage. Suggestions for further research are given.

Introduction

With the rapidly growing need for Science, Technology, Engineering, and Mathematics (STEM) professionals, there is a global growing demand for STEM graduates (OECD, 2016). Most western education systems cannot provide a high enough number of STEM students, leading to a current shortage of STEM graduates (OECD, 2016). This is seen as a problem by various STEM stakeholders, among other reasons because a large amount of unfilled STEM jobs could arguably stagnate scientific progress and subsequent economic instability (Rothwell, 2013). In addition, such a shortage can impair a country's upward social mobility, since STEM jobs are characterized by high chances of a successful career (Archer et al., 2020).

The Netherlands is one of the countries in which this phenomenon occurs on a relatively large scale, compared to other western countries. In recent years, a relatively low number of Dutch pupils enrolled in STEM education (OECD, 2016, 2017, 2020). Of these pupils, a substantial part initially shows talent for and interest in STEM, only to eventually leave education with a non-STEM-related diploma (TechniekPact & Platform Bèta Techniek, 2016). Moreover, recent data shows an increasing trend in dropout from STEM subjects in secondary education in the Netherlands (CBS, 2020). Despite awareness of this trend and a widespread demand to reverse it, no successful way to stop STEM dropout has yet been established.

This dropout in STEM education is sometimes referred to as "STEM pipeline leakage." In this metaphor, the pipeline stands for the educational pathway that begins at secondary education and runs via tertiary education to the labour market; The potential dropout moments along this pathway are called "pipeline leaks" (Alper, 1993; Berryman, 1983; Watt & Eccles, 2008). By excluding STEM subjects, students prematurely restrict their future educational options in STEM, since STEM subjects are often required for tertiary STEM studies. Similarly, STEM studies are often required for STEM jobs. This makes re-joining the pipeline at a later point (e.g., in the STEM labour market) hard and rare (Meece et al., 1990; Korpershoek, 2011). Detecting and understanding the factors influencing educational choices is a crucial first step to start preventing dropout ('fix the leak') from STEM education.

Several factors can influence students' decision to (dis)continue STEM education along their educational pathway, and various studies have attempted to describe and categorize these factors (e.g. Archer et al., 2020; Kemper et al., 2007; Van der Hurk et al., 2019; Van Langen & Meelissen, 2019). Although the studies subdivide the influencing factors differently, one can find important similarities between the overviews presented in these studies. For example, the studies agree that social environment (e.g. family and friends), school context (e.g. teaching pedagogy and school climate), and gender partly explain students' science aspirations. Also mentioned were dominant educational and social representations of people working in science (i.e. stereotypes) and other personal background variables apart from gender (e.g. socio-economic status and ethnicity).

The majority of these factors has already been well-investigated. Gender, for example, has been found to be a key factor in a student's attitude towards STEM, and many studies have aimed to pinpoint why female students are underrepresented in STEM education in order to propose solutions (e.g. Kemper et al., 2007; Korpershoek, 2011; Morgan et al., 2011; Unfried et al., 2014). But despite the relative wealth of studies, one factor that, to our knowledge, remains underrepresented is to what extent and in what way STEM teachers influence students' educational choices. Therefore, the main research question of this study is as follows:

> What role do high school STEM teachers play in the decision-making process of Dutch students to (dis)continue STEM education?

As the literature demonstrates that there is not one dominating factor in a student's tertiary educational choice, this research will focus on the role of STEM teachers relative to other influencing factors. Insights into the role of STEM teachers on students' decisions can help determine if and how STEM teachers influence students' choices to (dis)continue STEM education, in order to find solutions to the increasing STEM pipeline leakage, and, ultimately, to overcome the troublesome shortage of STEM-professionals in the labour market.

Theoretical background

The theoretical background to this thesis consists of three parts. Firstly, the potential dropout moments in the Dutch education system are explained. Secondly, known factors influencing students' educational choices are presented. Lastly, a selection of the research on the degree of STEM teachers' influence on students' educational choices is described.

Dropout moments in the Dutch education system

As mentioned before, the educational pathway in STEM ("STEM pipeline") has different potential dropout moments ("pipeline leaks")(Alper, 1993; Berryman, 1983; Watt & Eccles, 2008). Within the Dutch education system four main potential dropout moments can be identified for students in pre-university education, also known as 'VWO' (see Figure 1)(Korpershoek, 2011; Van Langen & Meelissen, 2019). Out of the four potential dropout moments, only the first two dropout moments (subject cluster choice and study choice) will be discussed as the dropout is at its highest here. The other two potential dropout moments are beyond the aim of this study.

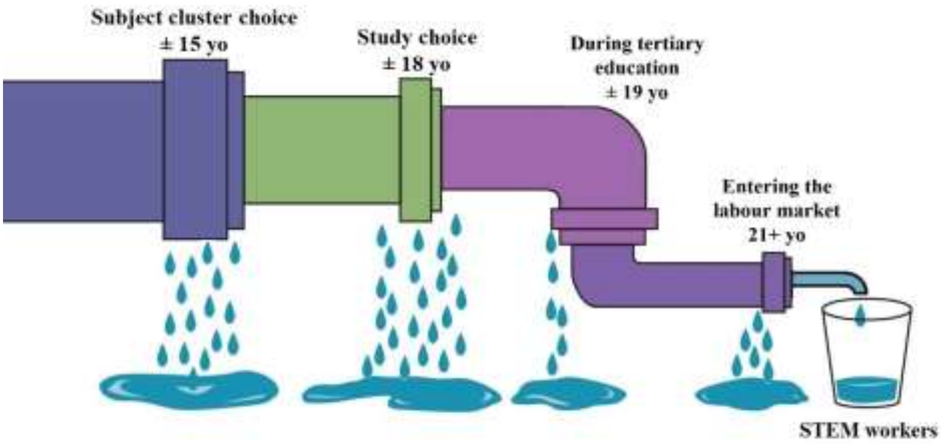


Figure 1. STEM education pipeline showing the largest four dropout moments in the Dutch education system and the students' ages at which they need to make the corresponding choices (adapted from Van Langen & Meelissen, 2019).

The first potential dropout moment, as illustrated in Figure 1, is at the moment of the subject cluster choice (Korpershoek, 2011). At the end of the ninth grade, when students are about fifteen years old, they have to make a subject cluster choice. Students can choose between four possible subject clusters, all with a specific set of mandatory and optional subjects (see Table 1).

Table 1. The four different subject clusters with their mandatory subjects and assigned labels.

Subject cluster	Mandatory subjects	Assigned label
Nature & Technology (N&T)	physics, chemistry, and advanced mathematics	"STEM cluster"
Nature & Health (N&G)	(advanced) mathematics, biology, and chemistry	"life Science cluster"
Economics & Society	(advanced) mathematics, economics, and history	"non-STEM cluster"
Culture & Society (C&M)	(advanced or basic) mathematics and history	"non-STEM cluster"

As shown in Table 1, one of the four subject clusters is dedicated to STEM ('N&T'). The two non-STEM subject clusters do not automatically include STEM subjects except for mathematics–but one should keep in mind that students could still elect one or multiple STEM subjects.

Between 2008 and 2019, on average about one in six pre-university students are documented to have opted for a the STEM cluster. In addition, on average approximately one in five students has chosen the Life Science cluster (CBS, 2020). Unfortunately, the amount of students choosing a non-STEM cluster with additional STEM subjects is unknown. Notably, the percentage of students choosing the STEM cluster is currently at its lowest since 2008 (CBS, 2020), while the popularity of the Life Science cluster is on the rise.

The second potential dropout moment is the transition from secondary to tertiary education, when students have to choose a tertiary study. Not all students who chose a STEM cluster or Life Science cluster continue in STEM education. Van Langen & Meelissen (2019) studied the official education data for a cohort of all Dutch students who graduated from pre-university secondary education in 2010 and entered the labour market between 2015 and 2018. From the students with a STEM cluster, 21% chose a non-STEM study, while 59% of the students with a Life Science cluster did so.

Factors influencing educational choices in general

Educational choices are often complex and multifactorial; a large number of factors can affect a student's decision-making process. This has been the subject of various (review) studies (e.g. Akosah-Twumasi et al., 2019; Archer et al., 2020; Draijer et al., 2017; Kemper et al., 2007; Van Langen & Meelissen, 2019; Zandwijk, 2020). As mentioned before, the studies show a significant overlap.

To create a more comprehensive overview of factors influencing educational choices, a guiding frame was constructed based on factors mentioned in these studies (See Table 2). The table is adapted from Van der Hurk et al. (2019) and has been enhanced by conclusions from the additional studies mentioned in the table. In Appendix A, the factors are discussed in full. Since the factor 'teachers' is closely related to the research question, this factor will be discussed extensively in the remainder of this paragraph.

Table 2. Overview of all factors known to influence educational choices, as gathered from literature.

Main categories	Factors and notable subfactors (bullet points)	Significant references
Malleable student characteristics	Interest	(Bloemen & Dellaert, 2000; Holmegaard et al., 2014; Mikkonen et al., 2009; Zandwijk, 2020)
	Attitude	(Morgan et al., 2011)
	Performances	(Van Langen & Meelissen, 2019; Zandwijk, 2020)
	Motivation	(Deci & Ryan, 1985; Wang & Degol, 2013; Zandwijk, 2020)
	Behaviour • Perceived behavioural control	(Deci & Ryan, 1985; Ootes, 2012)
Non-malleable student characteristics	Ability	(Hofkins, 2017)
	Aptitude	(Hofkins, 2017)
	Previous educational choices (e.g. subject cluster choice)	(Van Langen & Meelissen, 2019)
	Previous informal STEM experiences	(COSMOS Corporation, 1998)
	Personal background variables • Gender • SES • Personality • Ethnicity • Activities/hobbies	(Archer et al., 2020; Hofkins, 2017; Kemper et al., 2007; Korpershoek, 2011; Morgan et al,. 2011; Van den Hurk et al., 2019; Van Langen & Meelissen, 2019)
Social environment	Peers/friends	(Draijer et al., 2017; Tey et al., 2020; Van Langen & Meelissen, 2019)
	Family • Parents	(Hofkins, 2017; Draijer et al., 2017 ; Tey et al., 2020)
Regional-cultural characteristics	Educational policy	(Morgan et al., 2011)
	A country's level of development	(Morgan et al., 2011)
	Labour market/economy • Expected job opportunities • Interest in future job • Expected employment options • Variety of job options	(Akosah-Twumasi et al., 2019; Hofkins, 2017)
	Stereotypes • 'Clever' science • 'Masculine' science	(Archer et al., 2020)
School context	Organization • Educational gatekeeping (selection)	(Archer et al., 2020)
	School climate • School/study size • School type (religious, single-sex) • School status • Grouping practices (setting by ability) • Geographical setting • Content STEM curriculum • Schools' information supply on STEM studies	(Kemper et al., 2007; Ootes, 2012; Tripney et al., 2010; Van Langen & Meelissen, 2019)
	Teachers • Teaching pedagogy • Qualifications • Teachers' motivation • Teaching vision • Gender • Role models • Personality	(Akiba et al., 2007; Ammermüller & Dolton, 2006; Buday et al., 2012; Hill et al., 2010; Hofkins, 2017; Korpershoek, 2011; Kemper et al., 2007; Kraker-Pauw et al., 2017; Milgram, 2011; Mohd et al., 2010; Stearns et al., 2016; Tey et al., 2013; Van Langen & Meelissen, 2019; Wang & Degol, 2013; Watt et al., 2013)

The influence of teachers on the decision-making process

The influencing factor teachers includes seven different sub-factors. Teaching pedagogy refers to the didactic method of teachers; it is found that students who are "well-taught" are less likely to drop out of mathematics and physics classes (Hofkins, 2017). Whether a teacher "teaches well" partly depends on teacher qualifications – such as certification level and amount of teaching experience (Akiba et al., 2007). Qualifications were found to be positively linked to student achievement and, as a consequence, may influence STEM persistence (Akiba et al., 2007). For secondary education in the Netherlands, teachers should either have a partial teaching degree – to teach lower secondary school students – or a full teaching degree – to teach both lower and upper secondary school students (Rijksoverheid, n.d.). However, due to the current shortage of (STEM) teachers in the Netherlands, schools are sometimes forced to hire teachers who are less than fully qualified. In 2018, 8.8% of high school technology teaching hours was given by unqualified teachers. For mathematics this was 6.0% (Rijksoverheid, 2019). Even though these percentages appear relatively low, they represent thousands of secondary students receiving education from non- or underqualified teachers.

Where STEM teachers' motivations ideally include ability beliefs and altruistic "social utility", some teachers choose teaching as a fallback or second choice career, or as a career better compatible with family life (Kraker-Pauw et al., 2017; Watt et al., 2013). As Watt et al. (2013) note, teachers "who defaulted into STEM teaching as a fallback career subsequently reported more negativity in their interactions with students" (p. 198). In relation to this, this subset of teachers may hold an inferior teaching vision, which is also a factor that can influence students' educational choices, including teacher's beliefs about the nature of intelligence and their expectations of students achievements. Teachers who think of intelligence as malleable have been shown to exert a positive influence on students' motivation and grades (Wang & Degol, 2013). High student expectations demonstrate a similar effect (Wang & Degol, 2013).

The impact of STEM teachers' gender is relatively well-researched. In the Netherlands, most STEM subjects are taught by male teachers, which is notable since teaching in general is mainly a feminised profession in the Netherlands (CBS, 2018a). For example, in 2016, 83% of physics teachers and 82% of technology teachers was male. In subjects such as chemistry and mathematics 62% resp. 66% were male (CBS, 2018b). This may lead to the dropout of female students from STEM education, since same-gender teachers enhance students' educational achievements and study choice is strongly impacted by students performance (Ammermüller & Dolton, 2006; Van Langen & Meelissen, 2019). Indeed, Stearns et al. (2016) found that girls "are more likely to major in STEM fields and to graduate with STEM degrees when they come from high schools with higher proportions of female math and science teachers" (p. 87). Moreover, female teacher support is recognized as an important factor for young girls in math and science, in which the teacher has the capacity to function as a role model or mentor (Buday et al., 2012).

The importance of teachers as role models is not only restricted to gender identification. Teacher role models in general are reported as crucial in choosing a STEM-related career (Hill et al., 2010; Milgram, 2011). Similarities between teachers and students in traits other than gender may thus be an obscured influencing factor for explaining educational choices. This leads to the final sub-factor, teacher personality, which may determine the extent to which teachers function as their students' role models. The (lack of) similarities in personality between a student and a teacher has been reported to either attract students to or steer students away from the teacher's discipline (Mohd et al., 2010; Tey et al., 2020).

Degree of STEM teachers influence on students' educational choices

Previous research on the extent to which teachers influence students' educational choices is somewhat ambiguous. On the one hand, several studies report that teachers can significantly influence students' educational choices (e.g. Akosah-Twumasi et al., 2019; Bergin, 2016; Cheung et al., 2013; Hofkins, 2017; Howard et al., 2009; Humayon et al., 2018). On the other hand, for example, Tey et al. (2020) found that teachers have little influence on students' interest in STEM or on their intended career choice. Akosah-Twumasi et al. (2019) explain this difference in study results by the differing levels of parental education between countries; in certain countries, teachers have more impact on students' lives then parents.

Although studies in the Netherlands rate the impact of parents higher than of teachers, these studies also stress that teacher influence is not negligible (Kemper et al., 2007; Korpershoek, 2011). But to what extent Dutch (STEM) teachers influence students' educational choices has, to our knowledge, not been investigated yet. In addition, there is a lack of research which investigates what Dutch students themselves report on the influence STEM teachers had on their educational choices, and in-depth qualitative data is hitherto missing too.

Methods

An exploratory approach was chosen for this research for two main reasons. First, because little was known yet about the influence of teachers on educational choices, making it wise to start on a small scale and get in direct close contact with the students. Second, because this allows the possibility to unearth novel influencing factors and associated elements of the decision-making process.

For this exploratory descriptive study, in-depth semi-structured interviews with first-year tertiary students were conducted to find out what they report on the influence of their previous STEM teachers on their educational choices. Interviews were conducted with Microsoft Teams, due to social restrictions in force during the SARS-CoV2 pandemic. Data were open codes for quotes explaining the role of STEM teachers in students' educational choices.

Participant recruiting

Twelve Dutch first-year tertiary students (six male and six female, age 18 to 20), were recruited from the undergraduate student population of Utrecht University. This number of students was chosen because "it has previously been recommended that qualitative studies require a minimum sample size of at least twelve to reach data saturation" (Vasileiou et al., 2018, p. 7). Participants were recruited via randomly selected tutors of first-year classes from different STEM and non-STEM studies. Tutor participation was requested via e-mail. Tutors invited students to participate voluntarily. All students who fit the profile were included in the study. These students had to have completed pre-university education before enrolling in their tertiary studies, to improve comparability. One of the twelve students had switched subject cluster during secondary education and four students had switched study. Students who eventually participated were students who enrolled in Economics, Psychology, Chemistry, Educational Sciences, Social Sciences, Philosophy, Biology, or History. In exchange for their participations students were offered a small reward, namely a free outdoor fitness training.

Students could in principle belong to one of eight groups, categorized by the variables gender, subject cluster type and study type (see Table 3). Possible study or cluster switches are not included in this preliminary clustering for practical reasons.

The original aim was to recruit at least one student for each of the eight groups. Unfortunately, as students of the F/N/S and M/N/S group did not come forward, these groups have been left out.

Table 3. Participant grouping. Groups are represented by three indicators which are respectively gender (F or M), subject cluster (non-STEM (N) or STEM/Life Science (S)), and study (non-STEM (N) or STEM (S)). Indicators are demarcated with slashes (/). F/S/N, for example, are female students who chose a STEM or Life Science subject cluster and then a non-STEM tertiary study. n = number of students.

	Female	n		Male	n
Non-STEM cluster + non-STEM study	F/N/N	2		M/N/N	3
Non-STEM cluster + STEM study**	F/N/S	0		M/N/S	0
STEM/Life Science cluster* + non-STEM study	F/S/N	2		M/S/N	1
STEM/Life Science cluster* + STEM study**	F/S/S	2		M/S/S	2

* STEM cluster = 'N&T' subject cluster. Life Science cluster = 'N&G' cluster. Non-STEM cluster = either 'E&M' or 'C&M'.
** STEM studies include either full or partial STEM studies. Examples of full STEM studies are physics, mathematics, and engineering. Partial STEM studies are, for example, (veterinary) medicine, dentistry, and IT law. Classification is according the 'Centraal Register Opleidingen Hoger Onderwijs (CROHO)'(Dienst Uitvoering Onderwijs, 2020).

Data management

Prior to the start of an interview, participants were asked to read an information letter and gave their informed consent. Participants were debriefed after participating. For dissemination purposes, a laymen's summary was sent to participants after the research project was finished. For data collection, data handling principles, and data storage, the FI Data Management Protocol of Utrecht University was followed (Universiteit Utrecht, 2020). This means, among other things, that the Beta File System of Utrecht University was used for data storage. Ethical approval was acquired from the Ethics Review Board of the faculties of Science and Geosciences under number S-21538.

Instruments and data collection

The 20- to 30-minute one-on-one interviews took place digitally via Microsoft Teams. Interview questions were created in advance and were based on existing literature on influencing factors as a whole, and on (STEM) teachers in particular. It was intentional to not direct the participants towards answers about STEM teachers in particular, to prevent bias in their answers.

Examples of interview questions are:

1. How did you get to your choice of subject cluster/study?
2. Was there a teacher who influenced your subject cluster choice or study choice? If yes, what role did this teacher play in your study decision? (e.g. was advice given, did they serve as a positive role model, were they an information supplier?)
3. Do you think that the teacher could have persuaded you in your subject cluster choice or study choice?

The full interview protocol can be found in appendix B.

Data analysis

Recordings of the interviews were transcribed using 'edited transcription'. This transcription method aims not to transcribe each syllable but to communicate the meaning of the speech in the most natural way possible (Streefkerk, 2020). All stutters and stammers, *um*s and *er*s, and filler phrases such as the familiar "you know", were excluded. Sentences were tidied up in order to improve grammar or flow.

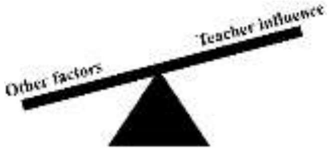
To identify key themes raised by students in the interviews, the transcripts were analysed using Burnard's approach, a well-known approach to bottom-up coding (Burnard et al., 2008). The first step in this approach is 'open coding'; quotes that summarise the meaning of the text are noted. Here, off-topic answers can simply remain uncoded. Next, an initial coding framework was generated. All overlapping or similar themes were removed and categories were further refined and grouped together. According to Burnard et al. (2008), a list of several categories (possibly up to a maximum of twelve) can then be compiled. This reduced list forms the final category system that is used to divide the utterances. Next, each transcript is worked through again twice, a process called 'constant comparison' (Burnard et al. 2008), to put data in their fitting categories. Finally, one ultimate file was created covering all quotes with their associated categories and the overall prevalence of categories in all interviews. Conclusions were based on this file (Burnard et al., 2008). In the report, key findings were described under main themes or categories using edited quotes from the interviews. Small extracts from the transcripts were translated to English for that purpose.

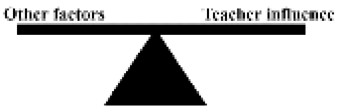
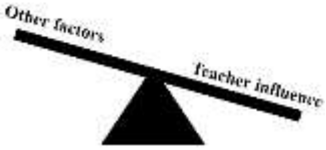
To abate the subjective nature of qualitative data analysis and to lessen biases, the analyses were verified and validated using second coding (Burnard et al., 2008). A total of 92 quotes were reviewed and categorized. For each category the amount of related quotes were tallied. All quotes were revised by a second coder, and interrater reliability was measured. Cohen's kappa, ($\kappa = 0.927$) indicated near-perfect interrater agreement (Mayer et al., 2004).

Results

Six main categories relating to teacher influence were derived from the interview transcripts, differing in the extent teachers had influenced students' educational choices in comparison with other influencing factors. Other factors, such as interest and performance, can either dominate over teacher influence, be on a par with teacher influence, or be dominated by teacher influence. Moreover, students can experience teacher influence as either positive or negative. These six categories are displayed in Table 4; the quotes are actual quotes from the interviews, added to illustrate the meaning of the categories. The full coding rubric can be found in appendix C.

Table 4. Descriptions of the six main categories. In the left column, a visual representation shows the relation between teacher influence and other influencing factors (such as interest, performance or enjoyment) in educational decisions. The balance shows which factor is most influential on the decision, or if both factors were of equal importance. The six main categories are mentioned in the middle column. The right column shows the corresponding example quotes, which are given to illustrate the meaning of each category. For prevalence of the categories in the interviews, see Figure 2.

Visual representation	Category	Example quote
	Other factors dominate positive teacher influence	"My chemistry teacher was a really nice guy and I just got along with him very well. But I did not necessarily like chemistry that much, because it didn't really connect to my personal life. – M/S/N student.
	Other factors dominate negative teacher influence	"Biology just interests me very much, even though my biology teachers were the worst teachers I have ever had. I had a female teacher for a few years and she taught all kinds of things that had nothing to do with biology. So, no, my teachers had no influence on my choice for studying Biology." – M/S/S student.

<table>
<tr><td rowspan="2"></td><td>Teacher as a positive catalyst</td><td>“I chose the study Biology, in part because it seemed like a really fun subject, in part because of how my high school teachers taught biology.” – F/S/S student.</td></tr>
<tr><td>Teacher as a negative catalyst</td><td>“My math teacher was somebody I really didn't get along with. Her lessons were like, ‘Okay, guys. This is the chapter, figure it out yourselves.’ So that was not a nice teacher. Also, I was never a maths genius anyway. So she probably could have never convinced me to study Mathematics.” – M/S/N student.</td></tr>
<tr><td rowspan="2"></td><td>Positive teacher influence dominates other factors</td><td>“I had a German teacher who was a real German, because he lived near the border of Germany. He talked enthusiastically about Cologne and all that, and that convinced me to elect German in my subject cluster, even though learning German was very difficult for me.” – F/N/N student.</td></tr>
<tr><td>Negative teacher influence dominates other factors</td><td>“I did like maths quite a bit, but my maths teacher was not so nice. I was good at maths and I had completed the course well. But my teacher was a bit of an average teacher. Maybe if I'd been doing a different study than the study I am doing now, and if I had had a very interested teacher, I may have enrolled to Mathematics.” – M/S/S student.</td></tr>
</table>

The three most frequently mentioned other influencing factors were interest (finding a subject/field interesting), performance (do well in a course) and enjoyment (enjoy a subject). On the latter factor, similar to Zandwijk’s (2020) experience, the word ‘leuk’ (Dutch; fun, nice, enjoyable) was often repeated by the interviewees, both when students talked about a specific teacher or about a subject.

Apart from these teacher-related categories, five side categories were determined. These categories provide additional information for understanding students’ multifactorial decision-making. The side categories are documented in the full coding rubric in appendix C and will be addressed later in this section.

Teacher categories

Looking at the six teacher categories (red/light pink bars in Figure 2), one can see large differences in the prevalence, varying from one to fifteen coded instances. In general the students more often mentioned described teachers as a positive influence (total 31 quotes) than a negative influence (total ten quotes). Only in rare cases was a teacher said to dominate over other influencing factors, be it negatively or positively. Interviews with male and female students resulted in comparable prevalence of coded instances between and within all six main categories. There were no categories in which only male or only female students were quoted, except for the category ‘Negative teacher influence dominates other factors’ as only one quote was coded for this category. Also there were no noticeable differences in quote prevalence between the represented genders who had made the same subject cluster choice and study choice. In addition, no obvious difference could observed between interviewees from the six represented participant groups.

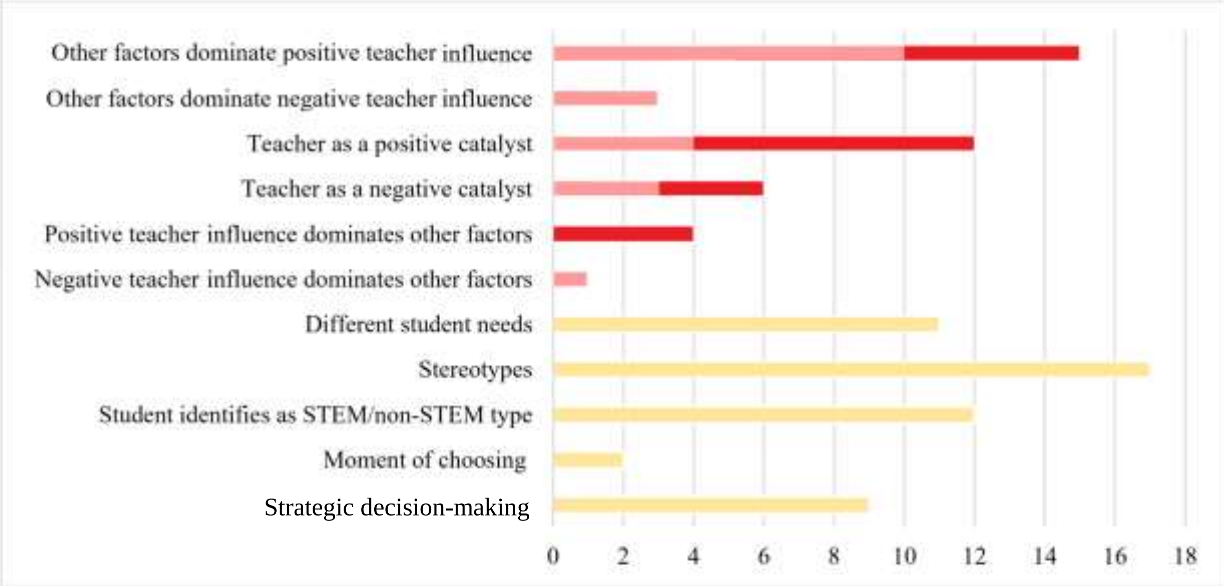


Figure 2. Distribution of categories, as coded from the interviews. The total of eleven categories are represented on the y-axis. The x-axis shows the prevalence of each category. Red/pink bars (top six) represent main categories, yellow bars (bottom five) represent side categories. The pink bars represent the amount of quotes of the total in which the discussed teacher was a STEM teacher. So for example the category ‘Teacher as a positive catalyst’ contains twelve coded instances, of which four out of twelve were mentions of a STEM teacher as positive catalyst.

As students were not prompted to talk about their STEM teachers specifically, quotes about both STEM and non-STEM teachers were obtained. Looking at the quotes on STEM teachers (pink bars in Figure 2), one can appreciate that STEM teachers were two times more often remembered positively (fourteen quotes) than negatively (seven quotes). Notably, the category ‘Other factors dominate positive teacher influence’ was significantly more prevalent than any other category. An illustrative quote on a STEM teacher in this category reads as follows:

> “I found physics and chemistry really difficult. Although I did have a very nice chemistry teacher. In fact, I liked that teacher so much that I almost chose chemistry in my subject cluster. However, as I was not really good at chemistry it would take a lot of work. Therefore, I did not choose chemistry in the end.” – M/N/N student.

Less prevalent was the category ‘Other factors dominate negative teacher influence’, which only included instances of STEM teacher influence. This category was mentioned by two students in total. Both students explained how they experienced their teachers’ appearance and/or taste as negative:

> “I was quite good at high school biology, but I did not like my teachers at all. They were very nerdy and boring, and they liked boring things. They also looked very weird. I just didn't like that at all.” – F/S/S student.
> “My biology teacher was an old man and he very much liked the computer science part of biology, which I did not like at all. We had to make a lot of reports and process a lot of data. So that didn't help with my decision to study Biology.” – M/S/S student.

The category ‘Teacher as a positive catalyst’ was more frequently assigned when students talked about their non-STEM teachers. Almost every interviewee mentioned a situation which fit this category. Remarkably, all these interviewees also mentioned their interest and/or enjoyment of the subject whenever they described the teacher as a positive influence. One student explained how she told her teachers that they motivated her to choose a certain STEM study:

> "I told my biology teachers that I wanted to enrol in Biology, partly because they got me motivated and partly because I was very much interested in biology myself. They saw that as a very big compliment." – F/S/S student.

Nothing about STEM teachers was mentioned when students talked about situations in which 'Positive teacher influence dominates other factors'. These quotes were about a geography, economics, German and French teacher. The interviewees described performance and aptitude as factors which were dominated by positive teacher influence.

The category 'Negative teacher influence dominates other factors' was used for only one student, who was talking about a STEM teacher. This student explained he was quite good at mathematics but because of his 'average teacher' he did not enrol in Mathematics (see also Table 4).

Notably, the interviewees, in general, mostly spoke about interest and performance as being separate to the teachers' qualities and characteristics.

Side categories

Looking at the quotes ascribed to one of the five side categories, it becomes clear that the teacher is only one of the factors within education that influence the decision-making process.

Firstly, many students stressed how a particular teaching strategy or combination of teacher characteristics influenced them positively while they said it influenced most other students negatively – or vice versa. These quotes were clustered in the category 'different student needs'. Secondly, when asked to describe different teacher types, most students gave stereotypical views of the STEM and non-STEM teachers. This totalled 17 quotes, the most of any category. STEM teachers were often described as more structured, more introverted, more traditional and less colloquial, when compared to non-STEM teachers. Some students, but not all, were aware of the stereotypes in their interpretation, and stressed that not all teachers could be generalized in this manner. No student explicitly mentioned the teacher's gender being of influence to their educational choices. In addition, one student explicitly described STEM subjects as being more difficult, as a consequence of which a formal teacher is more suitable:

> "There is a clear difference notable between non-STEM and STEM teachers. The non-STEM teachers take a much more personal approach when explaining. The STEM teachers are much more formal. I think that's because the subject material is simply more difficult and it is more difficult to make it relatable to the students' lives." – M/S/S student

Student's expectations of their teachers also seemed to play a role:

> "I always had the expectation that I would get a male teacher for mathematics and economics. Just because I think numbers are more male-oriented. For the empathic and cultural subjects I assumed that I would get a female teacher." – M/N/N student

Thirdly, students from all six interviewed participant groups identified themselves strongly as a STEM or non-STEM 'type'. Out of twelve students, two identified themselves strongly as a STEM type, four strongly as non-STEM type, two could not specify themselves as a specific type, and with four students the interview did not lead to the question of identification. One student who identified herself as non-STEM type said:

> "I think I'm just more non-STEM-oriented anyway and that my study suits me better than my subject cluster." – F/S/N student

Fourthly, two quotes mention the influence of a premature ‘moment of choosing’ (i.e., 9th grade) the subject cluster or study. Fifthly, a substantial amount of students reported their choice as being a strategic one, as choosing the STEM subject cluster was perceived to allow for the most study options of any cluster.

What constitutes ‘good’ and ‘bad’ teachers?

In addition to the five side categories, extra results could be obtained about what students report as being a ‘good’ or ‘bad’ teacher. Even though this was not directly relevant to the initial goal of the research, these results do affect how to interpret some quotes, and it would be more complete to mention these observations. When describing the influence their teachers had on their educational choices, all interviewees mentioned the significant effect of ‘good teachers’ or ‘bad teachers’. In an attempt to elucidate what constitutes ‘good’ and ‘bad’ in the experience of these students, the coded instances were revisited. It was found that, according to the participant group:

- A ‘good’ teacher has an enjoyable personality, is social, enthusiastic, kind, concerned with the student’s lives, and sensible to the class’ dynamics. A ‘good’ teacher can converse about subjects other than the course curriculum. Moreover, a ‘good’ teacher has high didactic skills and transcends the textbook.

  One of the students reported, for example:

  > “It is important that a teacher can explain the subject material clearly and that the teacher knows how to engage the class. And that they also try to connect with the pupils and form a relationship. It’s important to me that the teacher inquires about your life and not only your ideas about the course subject.” – F/N/N student

- A ‘bad’ teacher is inexperienced, quick to anger, unintelligent and fails to level with the minds of the students. During class hours, a ‘bad teacher’ sticks tightly to the textbook and often fails to maintain order. A ‘bad’ teacher approaches the class as a single unit instead of a collection of individuals with individual minds and needs.

  One of the students reported, for example:

  > “I hate teachers who read everything from the book and do not explain more than that. I had a teacher who read everything from the book, but then slower than if you would read it yourself. And if you said something, she was quick to anger. She totally couldn’t control the class either, and I don’t think she was very clever, no. So I thought she was really, really inadequate.” – F/S/N student

Conclusion

This study has aimed to answer the research question ‘What role do high school STEM teachers play in the decision-making process of Dutch students to (dis)continue STEM education?’

First of all, this study agrees to the oft-stated interpretation that factors influencing the decision-making process of students in secondary education are multiple and simultaneous (Van Langen & Meelissen, 2019). It can be concluded from this study that three levels of teacher influence on students’ educational choices can be distinguished, indeed differing by the nature of their interplay with other influencing factors. Teacher influence can either dominate over other factors, be on a par with other factors, or be dominated by other factors. The partial conclusions can be phrased as such:

If the student experiences the (STEM) teacher as positive…

- And other factors as negative, then the teacher influence is rarely reported as decisive in their educational choices;
- And other factors as positive, then almost all participants report situations of interaction between teacher and other factors, implying that the teacher has a catalysing effect in educational choices (more frequently in non-STEM subjects).

If the student experiences the (STEM) teacher as negative…

- Most students report situations of interaction between the teacher and other factors, implying once more that the teacher has a catalysing effect on educational choices;
- And other factors as positive (although this occurred infrequently), the negative teacher influence was rarely reported as decisive in educational choices.

When comparing quotes on STEM teachers to quotes on non-STEM teachers, it is observed that:

- Other factors are more likely to dominate over a positive STEM teacher experience, suggesting that STEM teachers have less influence over the decision-making process than non-STEM teachers.

Taken together, these results suggest that teacher influence can catalyse other influencing factors, such as interest and performance, but it rarely overrules these factors. Moreover, it is less common for STEM teachers than for non-STEM teachers to overrule other factors' influences. All in all, teacher influence is an existent but subsidiary factor in the educational choices of students in pre-university education.

Discussion

Implications

This study shows that the degree to which (STEM) teachers influence students' educational choices, in relation to other factors, may be relatively minor. To what extent, then, can STEM teachers function as a solution to the arguable problem of shortage of STEM graduates and workers? Importantly, a positive STEM teacher experience does not influence all students, but can greatly influence some. For example, for students who already show interest and talent in STEM but whose decision is not yet set on a STEM study, a positive STEM teacher experience can be the decisive factor. This observation suggest that for the purposes of counteracting STEM pipeline leakage, it may be more effective for STEM teachers to focus on supporting students who are already interested and talented in STEM subjects than on students who lack interest or enjoyment in the subject, or who strongly identify as a "non-STEM type".

Harackiewicz et al. (2016) support this statement with their study in which two phases of students' interest are described; one phase promotes interest and one phase capitalizes on existing interests. Harackiewicz et al. (2016) state that existing individual interest predicts educational success, including future educational choices and performance. When there is interest, learning would feel more effortless and students would be more likely to attend classes, pay attention, engage, pursue individual research, and process information effectively (Harackiewicz et al., 2016; Hidi & Harackiewicz, 2000). In line with this view, capitalizing on existing interest, by targeting students who are already interested in a STEM subject may be relatively most effective.

Focusing on supporting students who are already interested and talented in STEM subjects is also more desirable in terms of ethics. One can justly be sceptical about the purpose of directing students towards a certain educational choice. Guiding students towards the study that befits them, whether it be STEM or non-STEM, may indeed seem more “right”. As Korpershoek (2011) mentioned in their study: “many non-STEM students felt that a science or technical study would not fit them, whereas STEM students did perceive an adequate fit” (p. 139). Enthusing students for whom a science or technical study would be an adequate fit – students who have “STEM potential” – would be more sensical. On top of that, this study suggests that this is also more effective than focusing on the less-interested, less-enjoying and less-performing students instead.

Limitations

This study has several important limitations. Firstly, it is important to realize that this study uncovers influencing factors only to the degree that participants experience, remember and speak openly about. In this study, it was found that the interviewees mostly spoke about interest and performance as being separate to the teachers’ qualities and characteristics. It seemed like students were not aware of the influence teachers have over their interest, enjoyment and performance (Chittum et al., 2017; Xie et al., 2015). On another note, participating students of different gender did not report a different experience of teachers influence. Neither did any student explicitly mention the gender of their teacher to play a role in their attitude towards the subject, although some students did mention they had expected a male teacher in STEM courses. This suggests that even though students may notice gender inequalities in STEM courses, they do not openly reflect on it in the context of their study choice. Indeed, Boring (2017) argues that gender stereotypes unconsciously influence students’ higher educational choices. Thus, observations that were not consciously experienced, were forgotten for some reason, or were not enticed by the method of questioning, will be missed by this study’s approach.

The second limitation is that not all eight participant groups were represented, since no student could be reached of the groups F/N/S and M/N/S. As mentioned in the introduction, re-joining the STEM pipeline after choosing a non-STEM subject cluster is often an obstructed path in the Netherlands (Meece et al., 1990; Korpershoek, 2011), since it includes taking extra courses after graduating from secondary education. The amount of students who do so may be small and thus hard to find. Students are generally not inclined to change their initial study profile and they usually remain satisfied with their earlier study profile choice (Korpershoek, 2011).

Thirdly, quotes on STEM teachers in this study were relatively scarce. Only 21 in a total of 92 quotes explicitly concerned STEM teachers. It was intentional to not direct the participants towards answers about STEM teachers, to prevent bias in their answers, which may explain this low prevalence. But taking the relative low amount of quotes on STEM teachers into account, it could be recommended to have had invited more students of every group.

Future research

The results in this study can serve as a basis for a larger quantitative survey on teacher influence on educational choices. It is advised that the questions in such a survey are directed towards understanding the prevalence of the six main categories described in this study, as well as focus on the interaction between teacher influence and specific other factors (interest, enjoyment, performance etc.). The differences in influence between STEM and non-STEM teachers, as documented in this study, would also need to be further investigated in this survey.

In addition, it would be of interest to perform longitudinal observational or intervention studies to further analyse several of the mechanisms of teacher influence that have emerged from this and other studies. For example, if the cases in which teacher influence dominates over other factors are indeed rare, why is that? It would be interesting to further study the rare cases in which STEM teachers dominated over other influencing factors, to find out how STEM teachers could potentially have more direct influence over students' educational choices. Moreover, it would be interesting to study the prevalence of the negative and positive catalysing effects of teachers on students' educational choices, to find out the exact nature of this interaction.

Another factor which was revealed in this study was the relatively large prevalence of quotes on strategic decision-making, which mostly concerned keeping all options open for the study choice. It is imaginable that students who choose a STEM subject cluster for strategical reasons only postpone their decision on (dis-)continuing STEM education. Possibly, this may partly explain student dropout during tertiary education. It would be of great interest to further study the prevalence and dynamics of this influencing factor.

Notably, the observation in this study that certain students strongly identify as a STEM or non-STEM type appear, to our knowledge, to be quite unique in research on educational choices. Are these identities important influencing factors in the decision-making process? How do such identities form? And can such identities be shaped and reshaped by external factors? Such questions may be a basis for future quantitative research.

Indeed, the interviews in this study have uncovered a myriad of influencing factors and factor interactions, which hopefully direct research to, ultimately, better understand the interaction between teachers and their students in relation to their educational choices.

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Appendix A – Factors influencing educational choices

As shown in Table 2, there are five main categories of factors influencing educational choices: malleable and non-malleable student characteristics, social environment, regional cultural characteristics, and school context.

Malleable student characteristics

Malleable student characteristics is a term used by Van den Hurk et al. (2019) and encompasses five factors that are, to a certain extent, dynamic. Interest is one of these factors as a student's personal interest is thought to play a significant role in education choices. Bloemen and Dellaert (2000) found that students primarily choose a study because they simply find it interesting. Indeed, the shortage of STEM graduates is also often explained by students' lack of interest in STEM (Mikkonen et al., 2009; Holmegaard et al., 2014). However, in research of Zandwijk (2020), interest did not seem the be the most important factor influencing students' subject cluster choice. Interest might therefore be a more prominent factor with the study choice compared to the subject cluster choice.

Closely tied to interest is attitude, another malleable student characteristic. It was found that a positive attitude towards science is a primary determinant for future educational choices (Morgan et al., 2011). The factor performance is postulated by Van Langen & Meelissen (2019), who found that chances of progression to tertiary STEM education are greater when the average exam mark for STEM subjects is higher. Performances (and grades) also seem to be an important motivator for subject cluster choice, as evidenced from classroom observations (Zandwijk, 2020).

Motivation was also found to clearly play a role in the decision-making process to pursue STEM education (Wang & Degol, 2013). A student's motivation affects their behaviour. A somewhat older study found that motivation could be increased by increasing the amount study choices, as different options cause students to perceive much behavioural control (Deci & Ryan, 1985). However, perceived behavioural control was found to only play a minor role in study choice (Ootes, 2012). In addition, Zandwijk (2020) found that students are predominately guided by intrinsic motivation for their subject cluster choice.

Non-malleable student characteristics

Academic literature states five factors which are regularly labelled as non-malleable students' characteristics. Two of these, ability and aptitude are closely tied to performances. Once a student is able and apt in STEM subjects like mathematics or physics, the student is less likely to drop out of the STEM pipeline (Hofkins, 2017). Another non-malleable characteristic is a student's previous educational choices. The amount of STEM subjects included in a student's subject cluster positively correlates to the chances of choosing a STEM study after secondary education (Van Langen & Meelissen, 2019). Another discernible factor is previous informal STEM experiences, such as museum visits. It has been found that "many people with science-related careers credit their initial interest in STEM to informal rather than formal exposure" (COSMOS Corporation, 1998, p. 4).

Finally, personal background variables such as gender, SES, ethnicity, personality, and activities/hobbies are found to influence education choice (the latter two factors are arguably malleable). There is a growing body of literature focusing on these personal background variables explaining educational choices, and STEM choices in particular (e.g. Archer et al., 2020; Hofkins, 2017; Kemper et al., 2007; Korpershoek, 2011; Morgan et al,. 2011; Van den Hurk et al., 2019; Van Langen & Meelissen, 2019). In all education levels, female students are underrepresented in STEM and more female than male students drop out of STEM education during their educational careers

(Van den Hurk et al., 2019; Van Langen & Meelissen, 2019). Similarly, (non-Western) ethnic minorities and students with a low SES are more likely to drop out of STEM education compared to more socially advantaged students (Van Langen & Meelissen, 2019). Furthermore, personality also is an important determinant, as “students’ interests and, consequently, their subject choices are related to their personality” (Korpershoek, 2011, p. 49). It was found that the full STEM subject cluster seemed to attract more introverted students, whereas the other subject clusters attracted more extraverted students (Korpershoek, 2011). Lastly, the risk of dropout from STEM education decreases significantly when a student undertakes STEM activities or hobbies during spare time (Korpershoek, 2011).

Social environment
The following factors can be said to fall in the category of social environment: peers/friends, and family (including parents). The interest of students is shown to be influenced by the other students (Draijer et al., 2017). Remarkably, there is less dropout from tertiary STEM education when there is a substantial amount of female peers in class (25-50%)(Van Langen & Meelissen, 2019). Tey et al. (2020) have found that students’ STEM career choice intention is influenced by peers, though their STEM interest is not. In this same study, parents were found to have a significant influence on both students’ STEM interest and career choice intention. In line with this result, Hofkins (2017) found that students are more likely to continue STEM subjects such as mathematics and physics if they are encouraged by a key adult, such as their parents or a close family member. Students themselves report that their father has a greater influence on their STEM interest than their mother (Draijer et al., 2017).

Regional-cultural characteristics
Regional-cultural characteristics are found to have a more indirect effect on students’ educational choices by influencing school context, social environment and personal background variables (Dekkers, 2007). For instance, a country’s educational policy and level of development strongly affect attitudes towards science; in developing countries where secondary education is less accessible and therefore valued more, students are more positive towards science education (Morgan et al., 2011). Another factor is the state and character of the accessible labour market. This can be subdivided into several sub-factors, namely expected job opportunities, interest in future job, expected employment options, and variety of job options. When the regional labour marker is expected to be favorable for particular STEM jobs, students are more inclined to continue STEM education (Akosah-Twumasi et al., 2019; Hofkins, 2017). Lastly, dominant educational and social representations of science (i.e. stereotypes) were also found to play an important role in students’ educational choices. According to Archer et al. (2020), many students prematurely exclude STEM-related study and work options because they hold a negative view of the field. Stereotypical views of science as ‘clever’ (sometimes called ‘nerdy’) or ‘masculine’ are common and reinforce the exclusiveness of science (Archer et al., 2020).

School context
School context comprises three main factors, which can be divided into multiple sub-factors. The first factor, organization, includes educational gatekeeping (i.e. selection), which is known to channel and constrain students’ science choices, aspirations and progression (Archer et al., 2020). The next factor, school climate, comprises several sub-factors that all influence educational choices regards STEM (Kemper et al., 2007; Ootes, 2012; Tripney et al., 2010). While most sub-factors are self-explanatory, the content of the STEM curriculum and a schools’ information supply on STEM studies require further explanation. Regarding the content of the STEM curriculum, it was found that students appreciate the STEM field more when STEM subjects include more hands-on work and relate better to

a student's personal motivation and interests (Van Langen & Meelissen, 2019). With regard to schools' information supply on STEM studies, the risk of dropout decreases when schools organize joint visits to open days for tertiary education (Van Langen & Meelissen, 2019).

Appendix B – Interview protocol

Interview introduction

"Before we'll start the interview, I want to thank you again for your participation. In the informed consent you filled in prior to the interview, you indicated that you consent recording this conversation. Is this correct? I would like to emphasize that the recording will be anonymously stored on the servers of Utrecht University. The reports are strictly confidential and for internal use only.

Participation in this interview is completely voluntary. You are free to decline to participate for any reason. You may also stop participating at any time or refuse to answer any individual question.

As you may know, the purpose of the interview is to find out what the influence of teachers has been on the subject cluster choice and study choice of students. The interview will last approximately 20 to 30 minutes. Do you have any questions before we start the interview?

Interview questions (which allowed for follow-up questions)

- Do you enjoy your current study?
- How did you get to this choice of study
- Was there a teacher who influenced your study choice? If yes, what role did this teacher play in your study decision? (e.g. was advice given, did they serve as a positive role model, were they an information supplier?)
- Could you describe your high school teachers with whom you had a good connection?
- Do you think teacher X could have convinced you to choose study X?
- Was there a teacher who you saw as a role model?
- Could you describe a high school teacher with whom you did not have a good connection?
- What makes a good teacher good and a bad teacher bad?
- Was it easy for you to make a subject cluster choice?
- Was there a teacher who influenced your subject cluster choice?
- Final question: Was there a difference between STEM teachers and non-STEM teachers at your high school?

Debrief

Thank you for participating. As I mentioned in the beginning, this research is about the influence of teachers on profile and study choices. What I did not tell you in advance is that we are mainly interested in the influence of STEM teachers and how they could have ensured that students (not) enroll in a STEM study. Currently, there is a large shortage of employees in the STEM field and we are curious to know how high school teachers can make a difference in this. Could more female science teachers, for example, ensure that girls choose science studies sooner because they can identify better with the teacher? This is just an example, but we hope to find out if and how STEM teachers can make a difference in this. Would you like to receive information about the results afterwards, when the study has been completed?

Appendix C – Full coding rubric

Code	Description
Main categories	
Other factors dominate positive teacher influence	Participants reported having positive experiences with the teacher of a subject, but other negative factors such as lack of interest, enjoyment and/or poor performance caused the discontinuation in this education direction.
Other factors dominate negative teacher influence	Participants reported having negative experiences with the teacher of a subject, but other positive factors such as interest, enjoyment and good performance caused the continuation in this education direction.
Teacher as a positive catalyst	Positive teacher influence interacted with other positive factors, and was an important catalyser in the decision to continue in this education direction.
Teacher as a negative catalyst	Negative teacher influence interacted with other negative factors, and was an important catalyser in the decision to discontinue this education direction.
Positive teacher influence dominates other factors	Participants reported negative other factors, such as a lack of interest, enjoyment and poor performance. But a positive experience with the teacher of a subject caused the continuation in this education direction anyhow.
Negative teacher influence dominates other factors	Participants reported positive other factors, such as interest, enjoyment and good performance, but a negative experience with the teacher of a subject caused the discontinuation in this education direction anyhow.
Side categories	
Different student needs	Participants stressed that certain teaching characteristics positively influenced them, although it clearly negatively influenced other students (or vice versa).
Stereotypes	Participants described a stereotypical image of STEM teachers, for example in their characteristics or their gender.
Student identifies as type STEM/non-STEM	Participants strongly identified themselves as a STEM or non-STEM type of person.
Moment of choosing	Participants mentioned the moment of choice being of influence on their decision, for example that the decision could have been different had the choice come later in their life or educational career.
Strategic decision-making	Participants described strategic reasons to make a certain subject cluster choice, such as choosing a STEM subject cluster as this is often required for tertiary (STEM) studies.