Dropping out of STEM

WHY 10TH GRADE STUDENTS CHOOSE TO DISCONTINUE STEM SUBJECTS THEY HAVE ELECTED THE YEAR BEFORE

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Abstract

Discontinuing STEM (Science, Technology, Engineering and Mathematics) subjects is a global issue, since more employees in the STEM field are needed worldwide each year. However, in secondary education, fewer students are choosing for a STEM-related study profile and a relatively large number of students decide to drop STEM subjects later on. The aim of this study is to investigate the reasons why 10th grade students in the Netherlands discontinue STEM subjects. Twenty students who discontinued a STEM subject (biology, physics and two types of mathematics), they elected a year earlier were interviewed, as were the supervisors of the decision process, their deans. The results of the semi-structured interviews show that only one reason is mentioned by students and deans alike: the subject appearing to be too hard or too much work in 10th grade. In contrast, students report mostly autonomous reasons for their decisions: they decided they did not enjoy the subject anymore or they found out that the subject is not needed (anymore) for their self-determined goals. Deans report reasons such as miscommunication and the consequences of the pandemic - reasons not mentioned by the students- and they do not reflect on students' autonomous decisions. Students advised to improve the subject choice process by giving more information and letting them practise with 10th grade-level lessons during 9th grade. These implications can make it easier for students to elect a fitting subject cluster and thereby possibly contribute to less discontinuation in STEM subjects.

Key-words: STEM, subject cluster choice, reasons for discontinuing STEM, secondary education

Introduction

As a biology teacher I can testify first-hand to the number of students that stop taking my subject in grade 10, after having elected it in grade 9. This phenomenon is not limited to biology, but is prevalent in STEM (Science, Technology, Engineering and Mathematics) classes in general at the school of this study. In my own experience, students who discontinued biology often have a feeling of not being good enough. Students sometimes also substitute biology for another subject during the year, however having missed a part of the subject, students have to work harder to catch up, which causes them to run behind on other subjects.

Dropping out of a STEM subjects is also a global issue, since more employees in the STEM field are needed worldwide each year (Funk & Parker, 2018). According to the Pew Research Center, STEM employment in the US has grown with 79% since 1990. It is projected that this number will grow with another 11% in the 2021-2031 time period (U.S. Bureau of Labor Statistics, 2022). This situation is not unique to the US as a large number of European countries (among others Germany, UK, Belgium) have unfilled vacancies in the STEM field (Caprile et al., 2015). 21 of the 29 analysed countries have difficulties finding science and engineering professionals, which made it second ranked in the top 20 bottleneck vacancies at European level.. This is also seen in the Netherlands, as in the third quarter of 2021, a historic number of 105,100 vacancies were unfilled in the technical work field in the Netherlands (Techniekpact, 2022). Besides the vacancies in the technical work field, there were 30,500 unfilled vacancies in the health care field and 24,300 in computer engineering in the Netherlands. For comparison, there were 9,284,000 people working in the Netherlands at the time (CBS, 2023). These unfilled vacancies are a growing concern, as STEM is implemented in many facets of each people's lives (Carnevale et al., 2011). Perhaps the best

example of this is people's growing use of the internet and mobile phones, which is, among other reasons, one of the causes of rapid growth in computer related occupations (Zilberman & Ice, 2021). In addition to the daily implementation of STEM, it is necessary for innovation, national security and economic growth of a nation (Xue & Larson, 2015).

Given the trend in increasing numbers of unfulfilled STEM jobs, it is worrying that the number of students in STEM education has been the same in some countries, and has actually been decreasing in other countries over the past decades (Bottia et al., 2018; Statistisches Bundesamt, 2023). This trend is especially pronounced in the Netherlands, as in 2014, 51% of the pre-university education (vwo) and higher general secondary education (havo) students chose a cluster of STEM subjects (TechniekPact, 2022). In school year 2021/2022, this number has decreased to 45% (Figure 1). The number of students obtaining a STEM-related tertiary degree is also relatively low in the Netherlands: 22% out of all tertiary educated adults between 25 and 64 have a STEM-related degree (OECD, 2016, p. 45). It is possible that either less students choose STEM subjects at high school, or students discontinue STEM subjects they chose earlier. Data shows that the latter is increasingly the case in the Netherlands (Koperdraad, 2021). As an illustration, at the school which is the context of this study, 32 out of 171 students enrolled in a STEM subject, discontinue a STEM subject in 10th grade.

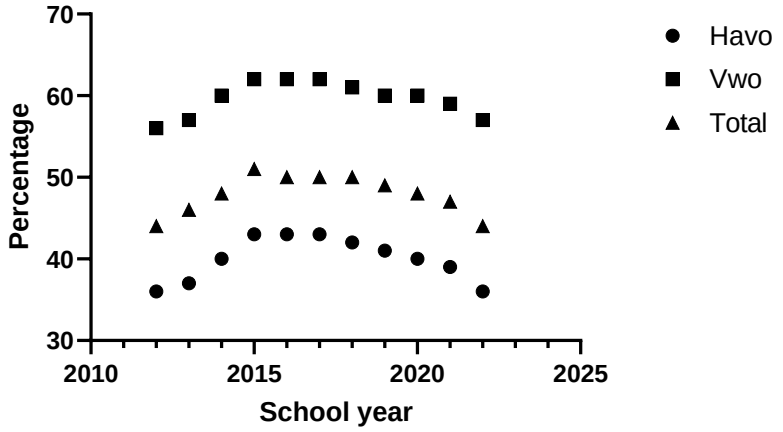

Figure 1: percentage of havo and vwo students with a cluster of STEM subjects out of all 10th grade students. (adapted from TechniekPact, 2022)

Students can drop out of the STEM field at various places, in a process referred to as "STEM pipeline leakage" (Alper, 1993). The pipeline in this metaphor is the educational pathway the students follow, while the leaks are the various places the students can stop with STEM. When either not choosing STEM subjects in the first place or dropping them later, secondary school students "leak" out of the pipeline. This makes it hard to re-join the pipeline at a later moment, since most STEM studies demand students to have had STEM subjects at high school (Feder, 2011; Grove, 2020). Similarly, STEM jobs almost always require having a STEM degree (Chadwick, 2017). To stop the pipeline leakage, understanding the reasons for dropping out of STEM subjects is important. As an ethical sidenote, note that the goal is not to make everybody choosing STEM studies, but rather to prevent the leaks as much as possible, to keep everyone in STEM who actually wants to be in STEM.

Many different reasons have been reported to influence educational choices (Archer et al., 2020; Kemper et al., 2007; van den Hurk et al., 2019; van Langen & Meelissen, 2019).

The most common determinants are: school climate, social environment and gender. While there is abundant research on determinants for educational choices, there a far less studies about why students discontinue STEM subjects and even less research on the students' own perceptions (van den Hurk et al., 2019). Research on this particular subject could lead to an improvement of the students' decision-making process and help prevent discontinuation of STEM subjects later on. Therefore, the main research aim of this study is to study secondary school students' reasons for discontinuing STEM subjects and the perceptions of their supervisors in this process, the school deans.

Theoretical background

In this chapter, the Dutch school system and factors influencing educational choices will be discussed and the research question is formulated.

Dutch school system

In order to position this research, some information on the Dutch secondary school system is relevant. In the Netherlands, students can be enrolled in one of three different types of education in high school (Rijksoverheid, n.d.-f). The three types of high school education in the Netherlands are: pre-university education (vwo), higher general secondary education (havo) and vocational education (vmbo). Only students who have completed vwo can get into university (Rijksoverheid, n.d.-d). Students who have completed havo can get into higher professional education (HBO) (Rijksoverheid, n.d.-d). Students who have completed vmbo can go to secondary vocational school (mavo) (Rijksoverheid, n.d.-e). This study focuses only on havo and vwo students as vmbo students have different subject clusters and choose these subject clusters at an earlier age (Rijksoverheid, n.d.-b).

In the Netherlands, students have to choose a subject cluster in the 9th grade: the subject cluster choice (SCC). (Rijksoverheid, n.d.-a, n.d.-c). They will partake in the subjects of their particular cluster for the remaining time of high school. The possible subject clusters are: Nature and Technology (N&T), Nature and Health (N&G), Economics and Society (E&M) and Culture and Society (C&M). Each subject cluster has mandatory subjects and optional subjects (Table 1). N&T and N&G are considered STEM subject clusters, while E&M and C&M are not. It is possible to choose a STEM subject in a non-STEM subject cluster, meaning students in all subject clusters in principle are free to elect STEM classes in upper secondary education. Subjects that are considered STEM are: biology, chemistry, physics, math A or math B and, at some schools, computer engineering (Rijksoverheid, n.d.-c; Sariwating, 2022).

Table 1

Subject clusters and their mandatory subjects

Subject cluster	Mandatory subjects
Nature and Technology (N&T)	Physics, chemistry, and math B
Nature and Health (N&G)	Math A or B, biology, and chemistry
Economics & Society (E&M)	Math A or B, economics, and history
Culture & Society (C&M)	Math A (only vwo), French/German (only havo) and history

Students of all clusters have to choose between two fields of mathematics: mathematics A (match A) (focussed on statistics) and mathematics B (math B) (focussed on calculus). While both kinds of math are technically part of the STEM field, math B is considered to be more relevant to STEM than math A (Hammink & Hoeven, 2013), since it is supportive of such typical STEM subjects such as physics and chemistry. In some cases, it is possible to enrol in a "light" version of mathematics (mathematics C), but this is not considered a STEM subject (Klein Kranenbarg, 2020). Math B is mandatory for N&T and optional for N&G and E&M. While it is possible to choose math B for C&M, this does not happen very often (Spandaw, 2008). (Sariwating, 2022). In the 10th grade, students have a small timeframe in which they can still switch to another subject cluster, to discontinue non-mandatory elective subjects (Snippe, 2021), or to switch from math B to math A. At havo, the switch from math A to C is possible in C&M. Note that this is also the only subject cluster that can be followed without taking any math at all.

The SCC process starts in early 9th grade, usually in September (Broekema & Habraken, 2012). The students get information about the four different subject clusters and will take part in an inventory on what subject cluster might best fit their qualities and aspirations. Around October they have to make their first choice, and in February the students register their definitive choice. During this seven-month SCC process, multiple persons support the students. These persons are the dean, the teachers and the students' tutors ("*mentor*" in Dutch). The primary person responsible for guiding the process is the school dean. The dean usually has multiple classes and individual sessions with the students during the process. The teachers give the students information about the subject they teach, e.g. what it entails in 10th grade. The tutor is expected to monitor the students' socio-emotional state, so they can give personal advice to the student about what subject cluster they think fits them best.

Subject cluster choice

As discussed in the introduction, the loss of students following a STEM track can be compared to a pipeline with pipeline leaks (Figure 2) (Alper, 1993). The first possible leak is the SCC (van Langen & Meelissen, 2019). The second leak depicted in the picture is the study choice: students can choose STEM studies or non-STEM studies. The third leak is students discontinuing with their chosen studies. The last possible leak is students who completed STEM studies eventually not entering the STEM working field. However, in between the first two leaks, there is another leak: students who chose a STEM subject, discontinuing their subject. This is the leak that is most relevant to this study and will be looked further into. The other leaks are not relevant to this study and will not be explained further.

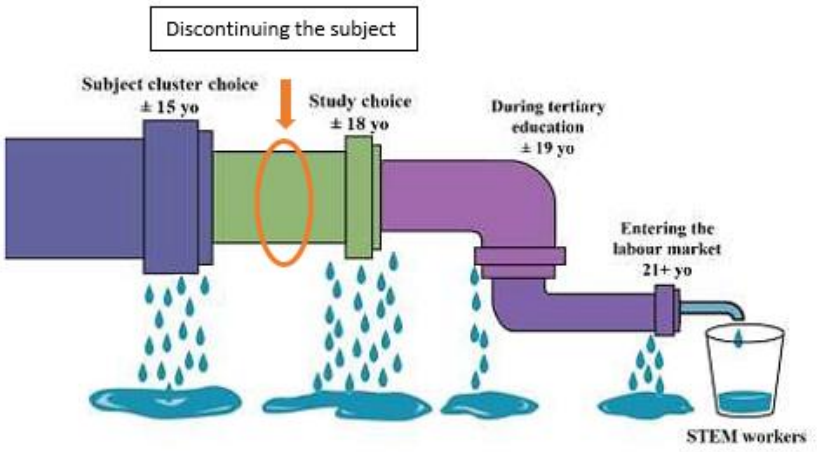

Figure 2: the STEM pipeline with pipeline leaks. (adapted from Ahn et al., 2016)

Factors known as influencing on educational choices

There are a multitude of factors affecting educational choices and thereby possibly affecting choosing and discontinuing a subject cluster or electives (Koperdraad, 2021). The main categories for these factors are: student characteristics, social environment, regional-cultural characteristics and school context. In this section, these categories and their factors will be described. An overview is presented in the table and factors deemed most important, based on the literature, are discussed in detail (Table 2).

Table 2

An overview of all factors possibly affecting choosing and discontinuing STEM subject clusters or subjects with their respective categories.

CATEGORIES	FACTORS	REFERENCES
STUDENT CHARACTERISTICS	Motivation	(Deci & Ryan, 2008; Wang & Degol, 2013)
	Ability	(Reiss et al., 2011; Wang & Degol, 2013)
	Perceived competence	(Ceci & Williams, 2007; Durik et al., 2006; Wang & Degol, 2013)
	Interest	(Malgwi et al., 2005)
	Behaviour	(Deci & Ryan, 1985)
	Previous informal STEM experiences	(Melber & Brown, 2008)
	Personal background variables • Gender • Personality • Ethnicity • Activities/hobbies	(Archer et al., 2020; Draijer et al., 2017; Kemper et al., 2007; Korpershoek, 2010; Morgan et al., 2011; Reiss et al., 2011; van Langen & Meelissen, 2019)
SOCIAL ENVIRONMENT	Peers/Friends	(Draijer et al., 2017; Reiss et al., 2011; Tey et al., 2020)
	Parents	(Draijer et al., 2017; Reiss et al., 2011; Tey et al., 2020)
	Other family members than parents	(Reiss et al., 2011)
REGIONAL-CULTURAL CHARACTERISTICS	Educational policy	(Morgan et al., 2011)
	Country's level of development	(Morgan et al., 2011)
	Labour market • Expected job opportunities	(Akosah-Twumasi et al., 2018)

	• Interest in future job • Expected employment options • Variety of job options	
	Stereotypes • Clever • Masculine	(Archer et al., 2020; Cheryan et al., 2017; Reiss et al., 2011)
SCHOOL CONTEXT	Selection	(Archer et al., 2020; van Langen & Meelissen, 2019)
	School climate • School size • School type (religious, single-sex) • School vision • Geographical setting • Content STEM curriculum • School's information supply on STEM studies	(Kemper et al., 2007; van Langen & Meelissen, 2019)
	Teacher's influence	(Draijer et al., 2017; Reiss et al., 2011; Tey et al., 2020)

Note: this is an updated and revised version of the literature study performed by Koperdraad (Adapted from: Koperdraad, 2021).

Student characteristics

One main determinant consists of student characteristics. The first factor discussed here is *motivation*. Motivation plays a major role in deciding whether the students pursues with STEM subjects (Wang & Degol, 2013). According to Wang and Degol, motivation is a strong predictors of engagement to STEM and performance in STEM subjects. There are different types of motivation, which are broadly categorised as autonomous and controlled motivation (Deci & Ryan, 2008. Autonomous motivation can be intrinsic, i.e, when a task is its own reward because it is fun or interesting (Deci & Ryan, 2008). When people "*have identified with an activity's value and ideally will have integrated it into their sense of self*" (Deci & Ryan, 2008, p. 182), this is also referred to as autonomous. Controlled motivation is related to pressure (Deci & Ryan, 2008). In controlled extrinsic motivation, people's behaviour is the result of a possible reward of punishment ("carrots and sticks"). In controlled introjected motivation, people's motivation is based on factors like avoidance of shame, approval and ego. In the latter case, the pressure is internal. In the former, it is external.

Ability and *perceived competence* can also possibly influence the choice for STEM subjects (Reiss et al., 2011; Wang & Degol, 2013). Students are more likely to choose a subject when they have the ability to perform well. Perceived competence is similar to ability, but perceived competence is focussed on how students *think* they perform, e.g., poor math perceived competence plays a major role in female underperformance (Ceci & Williams, 2007; Durik et al., 2006).

Social environment

The evidence for the influence of social environment factors on SCC all suggests a significant influence of *parents* (Draijer et al., 2017; Reiss et al., 2011; Tey et al., 2020). The evidence on the influence of *peers* is a little more mixed, as Tey et al. only found an influence of peers on students' STEM career choices and not on their STEM interest in general, while Draijer et al. did find that peers influence students' interest in STEM. Reiss et al. are

indecisive in their results on the influence of peers. The role of other family members than parents is mentioned by Reiss et al., but not discussed in their conclusion.

Cultural characteristics

The most important factor in this category is *stereotypes* (Archer et al., 2020; Reiss et al., 2011). The stereotype that science, especially mathematics and physics, is just for men may demotivate women to pursue in STEM. This is mainly the case because of three reasons: a) masculinity in cultures can make a woman have lower sense of belonging compared to men, b) no sufficient early experience of women in STEM, c) women's estimations of their abilities in STEM are lower compared to men's perceptions of their own ability (Cheryan et al., 2017). Another stereotype, the association of STEM with "cleverness" may make people in general believe they are not right for STEM (Archer et al., 2020).

School context

Several STEM majors require a selection procedure, implying not all students will be admitted. This has been reported to demotivate students, withholding them from choosing a STEM subject cluster (Archer et al., 2020; van Langen & Meelissen, 2019). Another important factor is *school climate* (Kemper et al., 2007; van Langen & Meelissen, 2019). Different schools may have different climates that favor different choices. The particular school in this study advertises a profile focussed on art and culture and less explicitly on STEM (Vathorst College, n.d.). The evidence on the last factor, *teacher's influence*, is mixed (Draijer et al., 2017; Reiss et al., 2011; Tey et al., 2020). While Draijer and Reiss et al. found that teachers do have an influence on students' choice for STEM, Tey et al. did not find evidence for this.

Research question

All factors in the section above have been reported to influence educational choices such as the SCC. However, the mechanisms behind these choices (e.g., to enrol in STEM) are not always known. Furthermore, for some factors, the evidence of their influence on educational choices is mixed and there is a relative dearth on research dealing explicitly with students' discontinuing elected subjects. This is a knowledge gap: not much is known about why students choose to discontinue with their educational choice, in the case of this study: STEM. Therefore, the research question is:

Why do certain 10th grade students decide to discontinue STEM subjects they have elected a year earlier?

Since the students' own reports are the most important to answers the research question, the first sub-question is:

What do students report on their reasons for choosing and subsequently discontinuing STEM subjects in upper secondary education?

As mentioned earlier, deans play a pivotal role in the SCC, so it is important to hear their thoughts on students discontinuing STEM. Therefore, the second sub-question is:

What do deans report on students' reasons for choosing and subsequently discontinuing STEM subjects in upper secondary education?

It is interesting to find out whether above factors also influence the discontinuing of STEM subjects, thereby possibly contributing to reverting the downward trend of the number

of students in STEM. Note that with this focus, parents, teachers, and tutors are not interviewed, even though students will be asked to reflect on their influence on the decision-making process.

Methods

A qualitative descriptive approach for answering the research question was chosen, as this approach allows for an understanding of individual motives and experiences., mechanisms, and insights that may or may not be part of the present theory. This study is be descriptive, as it aims to describe the students' reasons for discontinuing STEM subjects.

Setting

The research was performed at a relatively large (>1000 students), urban school in the middle of the Netherlands. It is a modern school with a modern view on education: students have a great degree of autonomy, e.g. they can decide to take part in a lessons or to do a different assignment, or chose between different levels of tests (Vathorst College, n.d.). In consultation with their teachers they can to a large extent determine the way they want to learn. It is also special in another aspect, as it is a so-called *art-and-culture-school*. Art and culture are an integral part of the education at this school, and is emphasized more at this school than STEM subjects (which is apparent by the number of students in 10th grade enrolled in C&M / E&M compared to N&G / N&T: 141 and 72 respectively). For example, students can choose more art subjects at this school compared to other schools in the Netherlands. Additionally, art is implemented in other non-art subjects, e.g., students are regularly asked to make posters and other visual representations for other subjects outside of arts.

Participants

The main participants of this research were grade 10 students (age 16 to 17) who have discontinued a STEM subject they had elected in 9th grade (biology, physics, math A, math B) and 1 student who made a belated full profile switch from NG/NT to EM. For the purpose of this research, the school administration had shared information about which students discontinued a STEM subject, information that is generally available to all teachers at the school. All 32 students who have discontinued a STEM subject were reached out to by an e-mail, asking if they wanted to be part of a focus group, to explain why they discontinued a STEM-subject. Eventually, 20 agreed to take part (Table 3). All participants received a modest reward (chocolate) as compensation for their time and effort.

In addition to the students, both deans working at the school were also interviewed. The deans were chosen because they have the primary task of supervising the cluster choice process. They are expected to have the most knowledge about the SCC.

Informed consent

Prior to the start of the focus groups and interviews, all participants received an information letter on this study and gave their informed consent (Appendix A: informed consent).

Instruments

Semi-structured interviews using focus groups were performed according to a much-cited manual (Litosseliti, 2003). Focus groups were organized according to subject, which means there were four different focus groups on the following subjects: biology, math A and

math B (Table 3). Focus groups were used for the student interviews, because students are expected to be more open when they are amongst their peers (Guest et al., 2017). Students can react on answers of other students or build their views on one another (Litosseliti, 2003). There were three reasons for having different focus groups for each subject. First: it was important that students could relate to each other in the focus group and they may relate more when they have dropped the same STEM subject (Litosseliti, 2003). Second: focus groups needed to be limited in size as all participants need to have a chance to share their experience (Krueger et al., 2001). Last, it was thought there may be differences between answers in each STEM subject focus group and when using different focus groups the subjects could be compared to each other after analysis. In the results section, the results of the different student interviews are combined, as the answers could be categorized the same way. The differences that did appear are mentioned in the results.

Since the arguments for different groups are less applicable to the deans, they were interviewed individually.

Table 3

Overview of performed interviews with students

Focus group / Interview	**Subject / Subject cluster**	**Number of persons contacted**	**Number of persons in focus group / interview**
Focus group	Biology	6	5
Focus group	Math A	15	8
Focus group	Math B	4	3
Interview	Physics	4	1
Interview	N&G/N&T to E&M	1	1
-	-	**32**	**20**

As only 1 person of the physics group agreed to participate in the research, one one-on-one interview was necessarily conducted. The same applies to the subject cluster switch from N&G/N&T to E&M.

The interviews with the deans and the students were based on different protocols.

The question for the deans are presented below:

1. Is the discontinuing of STEM subjects something that costs a lot of time for you?
2. Which reasons do students in your experience give for discontinuing STEM subjects?
3. Are these different reasons compared to non-STEM subjects?
4. Why is it important to get to know the reasons of students discontinuing STEM subjects?
5. Have you tried anything to lower of number of students discontinuing STEM subjects?
6. Are there any solutions you want to try?

7. If you could interview the students about discontinuing STEM, what would you ask them?
8. Are there any other things I need to know about the SCC of discontinuing STEM subjects?

The questions for the students are presented below:

1. What do you think of 10th grade
2. What do you think of your SCC in 9th grade
3. Who has supported you with your SCC?
4. Was this support sufficient?
5. Why did you choose an additional subject?
6. Why did you choose the specific additional subject?
7. Why did you discontinue the (additional) subject?
8. What would you say to the deans to improve the SCC?
9. Are there any other things I need to know about the SCC or discontinuing STEM subjects?

The questions were chosen to answer the two sub research questions. Students were not only asked why they discontinued a subject, but also whey they chose it in the first place. This was done to give an insight what happened between choosing and discontinuing the subject. Students were also explicitly asked to come up with possible suggestions for improvement of the cluster choice process. The interviews were conducted in Dutch (Appendix B).

During the semi-structured interviews with student focus groups, students were invited to respond to one another to let the answers be as spontaneous and honest as possible. If a student was quieter than the others, this student was asked the question more directly to assure everyone could tell everything they wanted.

After every question in an interview, it was checked that everything was said about that particular subject, before moving on. Follow-up questions such as “why?”, “please explain?”, and “please give an example?” were used to obtain more depth and context.

Data collection and management

The interviews were taped and transcribed verbatim transcription, filtering out fillers like “erm” and “you know”, fixing grammar mistakes, and indicating vague parts (Streefkerk, 2022). This method is used to make the meaning of the answers of the students as clear as possible (Koperdraad, 2021).

Data is collected and stored according to the Freudenthal Institute Data Management Protocol of Utrecht University (Universiteit Utrecht, 2022). The data is stored in the Beta File System.

Data analysis

Open or inductive coding (Medelyan, n.d.) was used to code the self-contained quotes in the interviews. The framework presented in the theory will be visited again in the results to compare the known factors with the factors found in this study, but the decision was made to be as open as possible, since the framework is not constructed primarily to describe the SCC process with its particular determinants.

Quotes with similarities were binned and assigned a category name. After this, themes within the categories were made (Figure 3a) (Appendix C: codebook). The same method was used for the dean interviews (Figure 3b) (Appendix C: codebook). Categories and codes were the same for each student focus group interview. Codes for choosing and codes for discontinuing are the same in the student group. A separate coding scheme for students' suggestions was created, with three categories: *practice, information, time*. No sub-categories were apparent here.

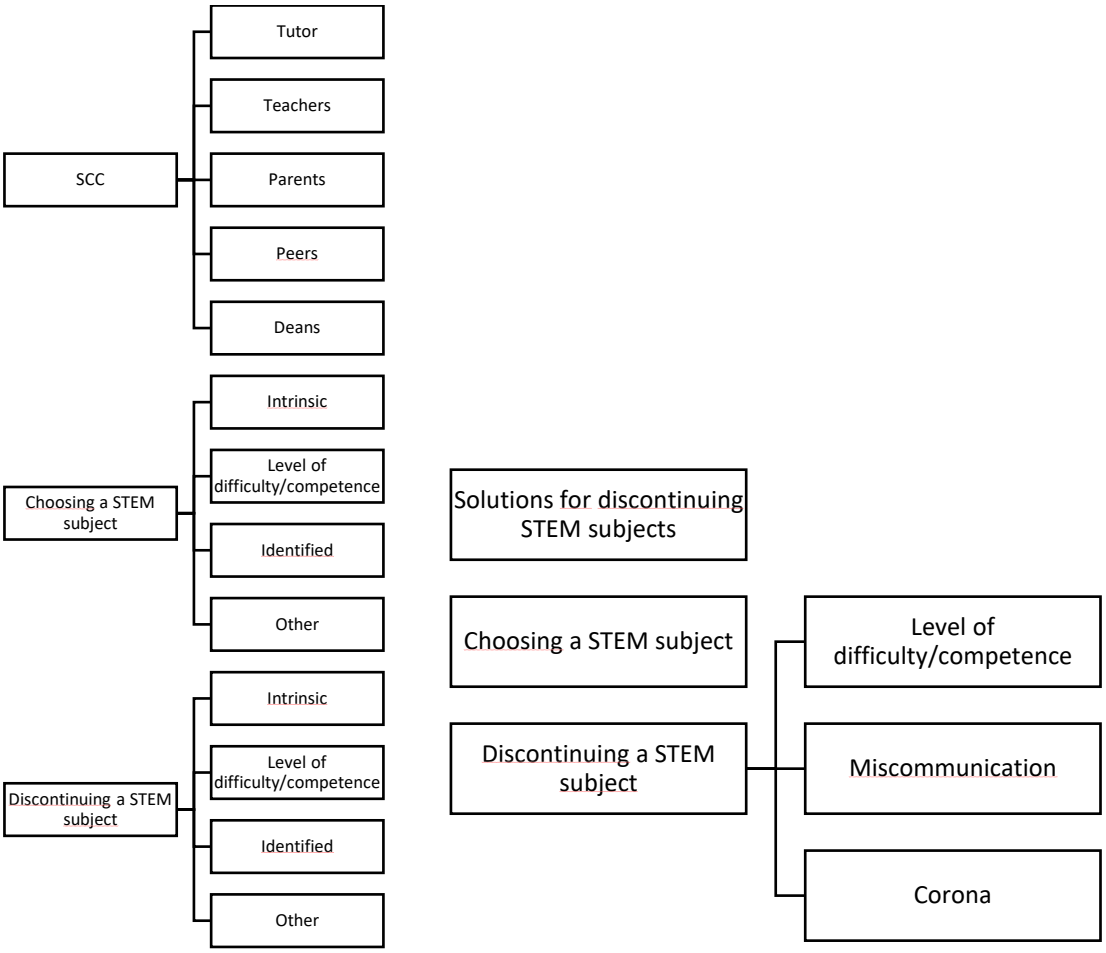

Figure 3a: coding scheme of students' answers **Figure 3b: coding scheme of deans' answers**

A second independent researcher has recoded part of the quotes in order to establish interrater reliability (Hallgren, 2012). The codes and quotes were given to the second coder, so the coder did not need to think of new codes. The level of agreement is measured using Cohen's kappa (Statology, 2021). As there were 3 different coding schemes used (students -159 quotes-, deans -20 quotes-, and advice from students -25 quotes-), three different values were calculated. The Cohen's kappa values were 0.93, 0.87, 0.90, respectively, indicating near perfect agreement.

Results

As mentioned earlier, all student interview results will be presented combined.

Support with SCC

The following persons are mentioned by the students as support during the SCC: *tutor, teacher, parents, peers* and *deans* (Figure 4).

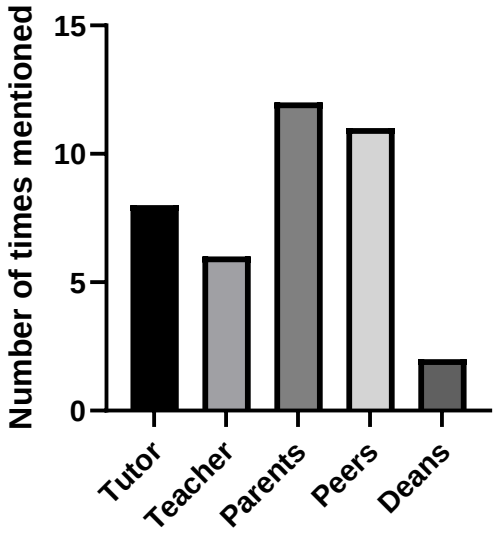

Figure 4: support mentioned by students (all subjects combined) during SCC process and/or discontinuing a subject (N=19). *Mentioned categories are: tutor, teacher, parents, peers and deans. The frequency of quotes in each category is shown on the vertical axis.*

Note that the categories do not distinguish between positive or negative quotes: e.g., the tutor is mentioned 8 times, but these quotes are predominantly negative such as: "[my tutor supported me during the SCC] but he didn't really help me. He just said that I should do what I wanted to". Most quotes about the teacher are neutral or slightly negative, for example: "Maybe [I] heard some things [about the SCC] sometimes from the teacher" or "[the teacher told] us: 'do not choose [a subject cluster] you enjoy but choose something that is useful' ". Teachers are not mentioned by the math B group or the subject cluster switch student.

Most student quotes refer to their parents: "[my parents said] 'that's not going to work out' [when I said I wanted to enrol in biology]. Parents are in some cases also perceived as supportive when talking about discontinuing a subject, or a whole subject cluster: "[I made a joke about switching to E&M and my mom told me:] 'now that you're telling me this, why wouldn't you?'". Peers are also mentioned as playing a role in supporting students: "[…] but I [discussed the SCC] predominant with my friends. [We asked each other] 'What are you going to choose?' […]".

While the deans play a major role in the SCC, only two students mention the deans as being supportive, one of which saying the deans let the teachers do most of the work: "[the deans did give some information about the SCC] but that information is passed to the teachers and they explain it [to us]". To illustrate this point more: when students did not talk about the dean when answering the question, they were asked specifically if they were helped by the dean. Most students said "no", while one student in one of the interviews asked: "what does the dean do again?"

Reasons for choosing a STEM subject

The students mention mainly 4 categories for choosing a subject: autonomous reasons (*intrinsic*: liking it or *identified*: needing it for self-determined goals), *the level of difficulty/competence*, and *other* (Figure 5).

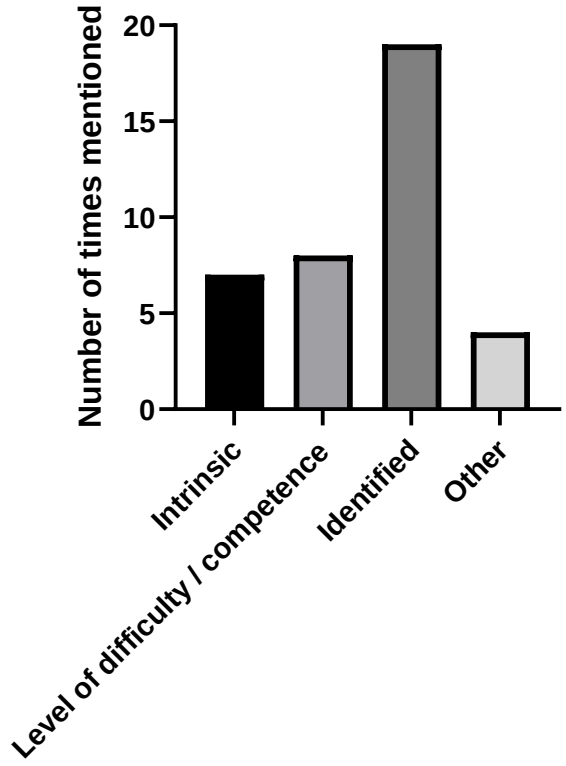

Figure 5: reasons for choosing a subject (cluster) mentioned by students (N=19). *Intrinsic (the subject being enjoyable), level of difficulty/competence (the subject being easy or the student being good at it), identified (the subject being needed for further education) and other. The frequency is shown on the vertical axis.*

The intrinsic reasons students mention are all "enjoyable". One student mentions: "I think [biology] is a fun subject [and that's why I choose it]". Interestingly, "fun" is mentioned six times in the biology group, while only one student in the math B group mentions it.

The level of the subject is also a reason for some students, for example: "[….] I [thought] I could do [math B] because I was good at it [at vmbo]". A large number of students choose a STEM subject because of identified reasons: they thought they needed it for their future plans. Some students needed the subject for their next education: "I wanted to be a nurse or a doctor [so I enrolled in physics]". Other students choose a STEM subject to be able to go to vwo later on: [I choose an additional STEM subject because] I wanted to go to vwo. Some things students mention in the *other* category are: "[I choose math B because] math B suits the STEM subject better than math A" and "In all other subject clusters [mathematics] is required so I thought it must me important".

Deans only mention one specific reason for students choosing a non-mandatory STEM subject within their profile: "to be sure". The deans: "[the students] choose an additional

[STEM] subject just to be safe" and "[students think] 'if I choose an additional [STEM] subject I can always drop it' ". Only two students explicitly mention this reason: one student says: "I thought I can drop [the additional subject biology] anyway, so [I can] just enrol in it and see if [biology] was just as easy as in the previous year". One other student says: "[I choose math A] to keep my options open".

Reasons for discontinuing a STEM subject

Reasons for discontinuing a STEM subject can be divided in the same categories as reasons for choosing a STEM subject, only with opposite connotations (Figure 6). Here, the intrinsic connotation of *enjoyable* becomes *not enjoyable*, *needed* becomes *not needed anymore* (for self-determined goals: identified) and *easy* becomes *too hard*.

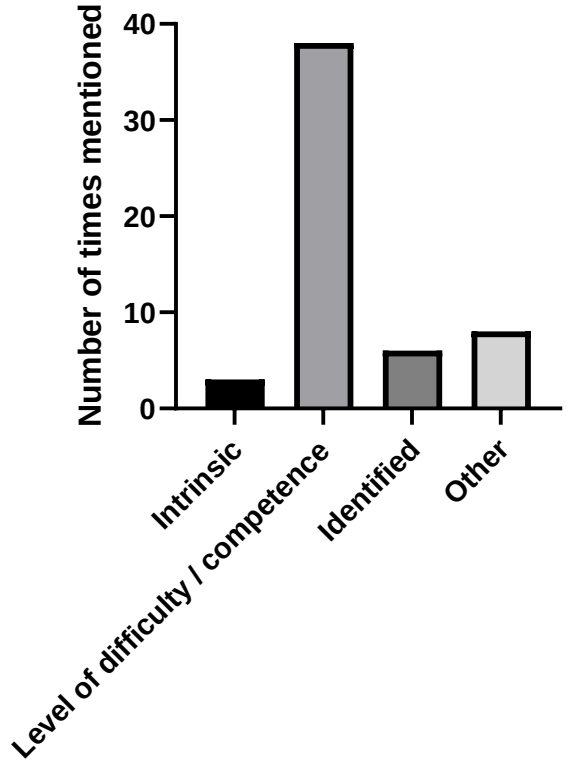

Figure 6: Reasons for discontinuing a subject (cluster) mentioned by students (N=19). *Mentioned categories are: intrinsic (the subject being not enjoyably), level of difficulty/competence (the subject being too hard or too much work), identified (the subject being not needed anymore for further education) and other. The frequency is shown on the vertical axis.*

A few students discontinued a STEM subject because the subject was no fun (anymore): "[biology] was not that much fun". This is also the case for the student who switched subject clusters completely: "[…] eventually I did not enjoy [STEM subjects] as much". A subject being not enjoyable is only mentioned three times, interestingly two times in the biology group, who also mention a subject being fun as reason for choosing it.

The reason mentioned most times is: *level of difficulty/competence*. The student who switched subject clusters says: "I thought especially chemistry was [hard and we had] too much to do". A student who discontinued math A says: "[mathematics is] just hard and eventually also too much". Another student who discontinued physics tells: "[physics and

chemistry] has suddenly became so hard so it is almost impossible to continue". The same student also has an answer in the category identified: "I was […] not so sure anymore whether I still wanted to become a doctor".

In the category *other* some interesting reasons are mentioned by the students: "it wasn't the teacher's fault [I discontinued biology], but maybe the method's], "[I discontinued physics] because I follow math A and that doesn't support physics like math B does", "I was distracting my friends so it was better for me to go", "[my teacher] couldn't motivate me […]. Maybe I could have done better [at math A if we got more attention]". One student discontinued math A because they discovered they have dyscalculia: "I am not good [at math and] I discovered later on I have dyscalculia".

The interviews with the deans yield only three categories in terms of reasons for students to drop STEM subjects later on: *miscommunication, level of difficulty/competence, corona* (Figure 7).

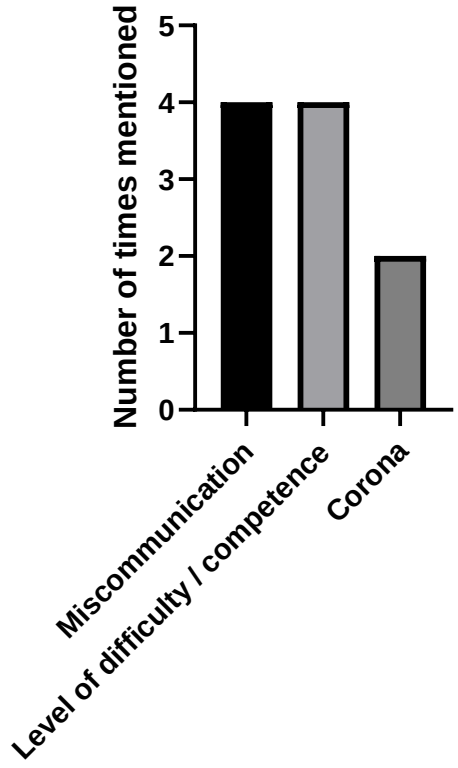

Figure 7: Reasons for discontinuing a subject (cluster) mentioned by deans (N=2*Mentioned categories are: miscommunication, level of the subject (the subject being hard or too much work), and corona. The frequency is shown on the x-axis.*

In the category *level*, deans say things like: "[students] think the workload is too high […], so they choose to discontinue the subject". This is especially the case with physics and biology: "physics is of too hard for [the students]", "biology is often too much work [for the students]". According to the deans, *miscommunication* is a recurring theme within the SCC: "the communication [about the subject cluster] is not clear anymore […]", "[…] the explanation [of the subject cluster] from the tutor to their students [is often not good enough]. Deans also indicate corona is a reason for discontinuing subjects: "[…] we have a lot more [discontinuations of subjects] now compared to before corona".

Advice from students to deans

Students were asked what they want to say to the deans to improve the SCC and thereby maybe reduce the number of discontinuations of subjects. Students answers can be divided in three categories: *practise, information* and *time* (Figure 8).

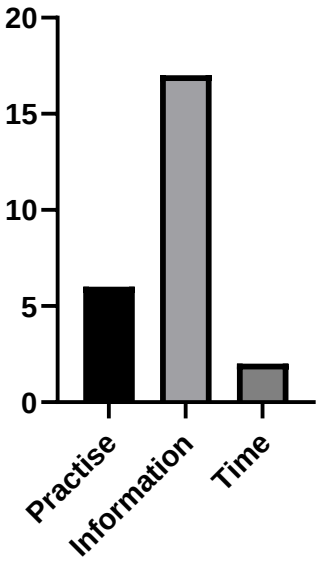

Figure 8: Students advise to the deans (N=19). *In this graph, categories mentioned by students giving advice to the deans about SCC improvement are shown. Mentioned categories are: practise, more information and more time. The frequency is shown on the x-axis.*

A number of student would have wanted more practise to choose a subject cluster. Some suggestions are: "I think [the teachers] can start earlier with teaching us [some 10th grade lessons] in 9th grade" or "You can learn best with doing, I think. So […] maybe one day we can get E&M lessons only and the other day N&G/N&T [so] we know what to expect". *Information* is mentioned most. Students say things like: "[I would have liked more information] from the dean […] or just from a teacher" or "[I would have wanted] that it is made clear [in 9th grade, what to expect] in 10th grade". *Time* is also something that some students would want more of: "we have spent so little time during the year [on the SCC].

Conclusion

To answer the first sub-question: *what do students report on their reasons for discontinuing STEM subjects in upper secondary education?* Students discontinue STEM subjects mostly for extrinsic autonomous reasons. The most mentioned category however, is the level of difficulty/competence, which is a non-autonomous reason. There are a few minor differences between each interview, but the overall consensus is the same. The answer to the second sub-question: *What do deans report on students' reasons for discontinuing STEM subjects in upper secondary education?* Deans report corona, miscommunication and the level of difficulty/competence as reasons for discontinuing. While the latter is a category of reasons mentioned by deans as well as students, it is the only similarity between them. The other reasons students and deans mention vastly differ from one another. This answers the main research question: *Why do certain 10th grade students decide to discontinue STEM subject they have elected a year earlier?* The students mention a wider range of reasons for discontinuing STEM subjects. While the deans report one similar category of reasons, their perception of the other reasons differ greatly. All the other categories students mention are

autonomous, while the reasons mentioned by the deans are not. The reasons will be elaborated below.

The students indicate sufficient support by their parents and/or peers during the SCC, two factors from the theoretical framework (Table 2). While some students state tutors and teachers supported them in the SCC and/or the discontinuation of subjects, this support was perceived as being insufficient by most of the students in our sample. Furthermore, deans are not mentioned by most of the students and those who do, do not speak positively about the deans. The deans' role in the SCC is deemed insufficient according to the students. It even looks like these students are not well aware of the function of the dean, illustrated by the one student who didn't know what a dean does at school.

The different answers students give compared to the deans when asked about choosing a subject (cluster) illustrates this discrepancy even more. Deans think students only have one reason to choose a STEM subject (i.e. "to be safe"), even when specifically asked for other reasons. While two students (in the same focus group) give the same reason as the deans, none of the other students do.

The most autonomous reason for choosing a subject mentioned by students is enjoyment of the subject, which can be labelled as intrinsic motivation (Ryan & Deci, 2000). The other reasons students indicated are extrinsic, but most of them still autonomous, e.g. needing a subject for their future, self-determined goals (identified motivation). This means most reasons of students' choosing a subject are related to (autonomous) motivation, ability or perceived competence, three factors from the framework (Table 2). As mentioned earlier, the reasons for discontinuing subjects are the same, but with opposite connotations. These reasons fit all categories of factors known as influencing educational choices, with the exception of regional-cultural characteristics. This may be due to the fact that the school is mostly white. Furthermore, the focus in the interviews was not on this category. It could be that if specific questions on this topic were asked, the students would have mentioned factors falling under this category.

The main takeaway from the students' advice is: students need more information about the SCC and in what kind of field they can work with the specific subject clusters. The category *information* which students mention often does have a connection with the deans mentioning *miscommunication* as a reason for students to discontinue a subject. It could very well be the case that the deans are able to identify miscommunication due to their experience at school and students cannot identify miscommunication as easily, hence not mentioning it as a reason for discontinuing a subject. The students mentioning the need of more information in the SCC seems to point at them experiencing consequences from the miscommunication the deans mention without the students really knowing it was a factor for them in discontinuing a STEM subject. The need for more time further underlines this. In fact, the students spend almost seven months during their 9th grade on the SCC. It seems the students mentioning a lack of time might also actually be referring to miscommunication, either due to the deans not informing the students in a timely manner about the SCC or due to the students not being involved enough in their own SCC. The comments about not enough time cannot be completely disregarded however, since the aim of the study is to get to know the students' own perceptions of the SCC and the discontinuing of subjects after this. In addition to more

time and information, multiple students indicate practise was something they would have benefited from. This way, they would have had a better idea what to expect in 10th grade.

The problem of STEM discontinuation at this school mainly lies in in the differing reasons perceived by the deans and the students for the subject dropout. A possible solution to this discrepancy is presented in the discussion section.

Discussion

Limitations

The first limitation one has to keep in mind when reading this study: this was a small study on one school in the Netherlands so the results only say something about this particular (*art-and-culture*) school. It is however possible that these results can found on other Dutch schools as well, as all Dutch havo and vwo high schools have a SCC and the process of choosing is about the same in each school (Onderwijsraad, 2011). Furthermore, the study does not include interviews with the teachers and the tutors.

Another possible limitation is the fact that only students who have discontinued a subject (cluster) were interviewed. This could be the reason that the students' opinions on the support of their SCC are predominantly negative. I could be that students who did not discontinue a subject perceive the process entirely differently. It was surprising that the dean is not mentioned often by the students as someone who supported them during the SCC. This again, may be due to the fact that the students who discontinued a subject did not pay attention or were not present at all during the deans' presentation.

The third limitation is that not all students who discontinued a subject wanted to participate in the study. It is possible that the students who did not join the study think the support given to them was sufficient. Furthermore, it is possible that those students had other reasons for choosing or discontinuing a subject.

The fourth possible limitation is the fact that the author of this study was a biology teacher of most of the students who discontinued biology. It could be that because of this, the students weren't perfectly honest with their reasons about why they discontinued biology. One of the follow-up questions after: "Why did you discontinue the (additional) subject?" was "did the teacher or the method also play a role?" If they teacher did play a role, there was a chance the student did not want to say it. On the other hand, this is not likely as the teacher only played a role according to one student in all the other groups.

Last, the interviews were conducted in different focus groups, but most results were presented combined. This was done because most answers fell under the same category. Since differences between groups are mentioned if there are any, combining the results of different focus groups has no likely effect.

Implications

A very practical takeaway of this study for this school is: let the students practise with 10th grade lessons while they are still in 9th grade. Students themselves mention more practise would have helped them making their SCC, thereby possibly making a better choice and preventing such large numbers of subject (cluster) discontinuation. When students experience some 10th grade level lessons before they have to make their subject cluster, they may be able

to make a more autonomous decision based on their experience instead of having to guess what the subject is like in 10th grade. The deans could play a coordinating role here.

A second takeaway for the school is: let students have more (perceived) time to make their SCC. Some students indicate they need it, and research on Dutch schools suggests parts of the educational pathway can benefit from having more time to choose (Onderwijsraad, 2021). The authors of the cited literature did research on delaying the choice between havo and vwo with two years (from one to three), but the conclusions can be translated to the SCC. Giving students a longer period of time to make their choice gives them longer to think about it and it can help them revising their choice before the definitive choice. It is even possible to have two instead of one non-definitive choice, to let the students experience how it feels to have made a choice for a subject cluster.

The last and most important takeaway is: communicate more and better. Both the students and the deans have made it clear that the communication about almost every aspect of the SCC is not perceived as sufficient. Students in our sample think they do not know enough to make a good SCC and do not know the consequences of discontinuing a subject. Both deans and students think the role of the tutor as well as the teachers are too small. Deans could communicate with the tutors and the teachers about what they have to tell about the SCC.

It is also important for the tutors to see the support in the SCC as one of their main roles in 9th grade. Communication between the tutors and deans is important: tutors could ask the deans for advice if they think they do not know enough about the SCC. Deans on their end need to make clear what they expect from the tutors. Last: the students themselves need to know that they are the ones who ultimately need to make the choice. They need to know they can ask for help instead of trying something on their own.

Apart from the implications on the school the research was performed on, this research can also be helpful for other Dutch schools. As mentioned earlier, little research has been performed on the SCC, let alone the discontinuation of subjects. This study gives new insights about the students' perceptions of the SCC and their reasoning behind discontinuing a subject (cluster). Other schools may benefit from this knowledge, as every school in the Netherlands has a SCC (Onderwijsraad, 2011).

Future research

As this is a study performed at one school, it would be interesting to do the same research at other schools (e.g. *technasium* schools, school where to focus is on STEM subjects) to see if the students' reasons for choosing and discontinuing are the same (Stichting Technasium, n.d.). It could also be interesting to interview teachers and tutors too, something that was not done in this study because of time limits. As teachers and tutors are known to be influential factors on educational choices, which is also confirmed by this study, it may be possible to give a better answer to the research question this way.

It would also be interesting to see if students who did not discontinue a subject (cluster) think the same about the support given in the SCC. As mentioned earlier, maybe only students who have discontinued a subject (cluster) think negatively about the support given. It could also be that the reasons for choosing a subject (cluster) are different for students who did not discontinue a subject (cluster). It may be interesting to compare the reasons for

choosing and see if the reasons of the students who didn't discontinue anything are more "valid".

The last suggested future research is following a number of students for a prolonged period of time in 9th grade during the SCC and in the 10th grade after the SCC, to get a longitudinal view of the process. It could also be interesting to monitor of the students' motives to choose a subject (cluster) change overtime. One can also implement the suggested changes by the students and see if the outcome is different when the students can practice with 10th grade subject in 9th grade of when the students are given more information or more time.

With this study and the suggested future research, a broader view on the SCC and discontinuing subjects can be created to help improve the SCC and maybe reduce the number of STEM dropouts.

References

Ahn, J. N., Luna-Lucero, M., Lamnina, M., Nightingale, M., Novak, D., & Lin-Siegler, X. (2016). Motivating students' STEM learning using biographical information. *International Journal of Designs for Learning, 7*(1), 71–85.

Akosah-Twumasi, P., Emeto, T. I., Lindsay, D., Tsey, K., & Malau-Aduli, B. S. (2018). A Systematic Review of Factors That Influence Youths Career Choices—the Role of Culture. *Frontiers in Education*, *3*. https://doi.org/10.3389/feduc.2018.00058

Alper, J. (1993). The pipeline is leaking women all the way along. *Science, 260*, 409–411.

Archer, L., Moote, J., MacLoed, E., Francis, B., & DeWitt, J. (2020). *ASPIRES 2: Young people's science and career aspirations, age 10-19*.

Bottia, M. C., Stearns, E., Mickelson, R. A., & Moller, S. (2018). Boosting the numbers of STEM majors? The role of high schools with a STEM program. *Science Education*, *102*(1), 85–107. https://doi.org/10.1002/sce.21318

Broekema, A. F., & Habraken, S. M. J. (2012). *Wat zal ik kiezen? Een onderzoek naar de overwegingen die een rol spelen bij het kiezen van een profiel in de derde klas*.

Caprile, M., Palmen, R., Sanz, P., & Dente, G. (2015). *Encouraging STEM studies; Labour market situation and comparison of practices targeted at young people in different member states*.

Carnevale, A. P., Smith, N., & Melton, M. (2011). *STEM*.

CBS. (2023). *Werkenden*. https://www.cbs.nl/nl-nl/visualisaties/dashboard-arbeidsmarkt/werkenden#:~:text=In%20het%20derde%20kwartaal%20van,toe%20met%20503%20duizend.

Ceci, S. J., & Williams, W. M. (2007). *Why aren't more women in science?: Top researchers debate the evidence.* (S. J. Ceci & W. M. Williams, Eds.). American Psychological Association. https://doi.org/10.1037/11546-000

Chadwick, S. (2017, June 18). *Can I get into a STEM career with a non-STEM degree?* https://www.stemgraduates.co.uk/blog/2017/06/get-into-stem-without-a-stem-degree

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, *143*(1), 1–35. https://doi.org/10.1037/bul0000052

Deci, E. L., & Ryan, R. M. (1985). Cognitive Evaluation Theory. In *Intrinsic Motivation and Self-Determination in Human Behavior* (pp. 43–85). Springer US. https://doi.org/10.1007/978-1-4899-2271-7_3

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology / Psychologie Canadienne*, *49*(3), 182–185. https://doi.org/10.1037/a0012801

Draijer, J., Bakker, A., Tromp, S., & Akkerman, S. (2017). *Interesses en studiekeuze van jongeren met bètatalent*.

Durik, A. M., Vida, M., & Eccles, J. S. (2006). Task values and ability beliefs as predictors of high school literacy choices: A developmental analysis. *Journal of Educational Psychology*, *98*(2), 382–393. https://doi.org/10.1037/0022-0663.98.2.382

Feder, T. (2011). Convincing US states to require physics. *Physics Today*, *64*(7), 29–30. https://doi.org/10.1063/PT.3.1163

Funk, C., & Parker, K. (2018). *Diversity in the STEM workforce varies widely across jobs*.

Grove, A. (2020, August 30). *What science courses are needed for college admission?* https://www.thoughtco.com/science-needed-to-get-into-college-788862

Guest, G., Namey, E., Taylor, J., Eley, N., & McKenna, K. (2017). Comparing focus groups and individual interviews: findings from a randomized study. *International Journal of Social Research Methodology*, *20*(6), 693–708. https://doi.org/10.1080/13645579.2017.1281601

Hallgren, K. A. (2012). Computing Inter-Rater Reliability for Observational Data: An Overview and Tutorial. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 23–34. https://doi.org/10.20982/tqmp.08.1.p023

Hammink, J. H. W., & Hoeven, R. (2013). *Profielkeuze vanuit leerlingperspectief*.

Kemper, P., van Hoof, J., Visser, M., & de Jong, M. (2007). Studiekeuze in kaart gebracht. *Tijdschrift Voor Hoger Onderwijs*, 270–279.

Klein Kranenbarg, L. M. (2020). *Het beeld van wiskunde C (bijgesteld)*.

Koperdraad, D. (2021). *How do high school teachers influence STEM pipeline leakage? An in-depth qualitative study*.

Korpershoek, H. (2010). *Search for Science Talent in the Netherlands*. Universiteit Groningen.

Krueger, R. A., Casey, M. A., Donner, J., Kirsch, S., & Maack, J. N. (2001). Social analysis selected tools and techniques. *Social Devlopment Papers*, *36*, 4–23.

Litosseliti, L. (2003). *Using Focus Groups in Research*. MPG Books Ltd.

Malgwi, C. A., Howe, M. A., & Burnaby, P. A. (2005). Influences on Students' Choice of College Major. *Journal of Education for Business*, *80*(5), 275–282. https://doi.org/10.3200/JOEB.80.5.275-282

Medelyan, A. (n.d.). *Coding qualitative data: how to code qualitative research*. Retrieved July 10, 2023, from https://getthematic.com/insights/coding-qualitative-data/

Melber, L. M., & Brown, K. D. (2008). "Not Like a Regular Science Class": Informal Science Education for Students with Disabilities. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *82*(1), 35–39. https://doi.org/10.3200/TCHS.82.1.35-39

Morgan, A., Choksi, B., Boujaoude, S., Swee Chin, N., van Griethuijsen, R., & Bag, H. (2011). *Science education for diversity: WP2*.

OECD. (2016). *Education at a Glance 2016*. OECD. https://doi.org/10.1787/eag-2016-en

Onderwijsraad. (2011). *Profielen in de bovenbouw havo-vwo*.

Onderwijsraad. (2021). *Later selecteren, beter differentiëren*.

Reiss, M., Hoyles, C., Mujtaba, T., Riazi Farzad, B., Rodd, M., Simon, S., & Stylianidou, F. (2011). Understanding participation rates in post-16 mathematics and physics: Conceptualising and operationalising the UPMAP Project. *International Journal of Science and Mathematics Education*, *9*(2), 273–302.

Rijksoverheid. (n.d.-a). *Hoe zit de havo in elkaar?* Retrieved February 11, 2023, from https://www.rijksoverheid.nl/onderwerpen/voortgezet-onderwijs/vraag-en-antwoord/hoe-zit-de-havo-in-elkaar

Rijksoverheid. (n.d.-b). *Hoe zit het vmbo in elkaar?* Retrieved February 11, 2023, from https://www.rijksoverheid.nl/onderwerpen/voortgezet-onderwijs/vraag-en-antwoord/hoe-zit-het-vmbo-in-elkaar

Rijksoverheid. (n.d.-c). *Hoe zit het vwo in elkaar?* Retrieved February 11, 2023, from https://www.rijksoverheid.nl/onderwerpen/voortgezet-onderwijs/vraag-en-antwoord/hoe-zit-het-vwo-in-elkaar

Rijksoverheid. (n.d.-d). *Met welke diploma's kan ik naar de universiteit of hogeschool?* Retrieved February 11, 2023, from https://www.rijksoverheid.nl/onderwerpen/hoger-onderwijs/vraag-en-antwoord/met-welke-diploma-s-kan-ik-naar-de-universiteit-of-hogeschool#:~:text=Met%20een%20havodiploma%2C%20een%20vwo,van%20een%20hbo%2Dopleiding%20nodig.

Rijksoverheid. (n.d.-e). *Uit welke mbo-opleidingen kan ik kiezen?* Retrieved February 11, 2023, from https://www.rijksoverheid.nl/onderwerpen/middelbaar-beroepsonderwijs/vraag-en-antwoord/uit-welke-mbo-opleidingen-kan-ik-kiezen

Rijksoverheid. (n.d.-f). *Welke schooladviezen kan mijn kind krijgen in groep 8?* Retrieved February 11, 2023, from https://www.rijksoverheid.nl/onderwerpen/schooladvies-en-eindtoets-basisschool/vraag-en-antwoord/adviezen-in-groep-8

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology*, *25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Sariwating, K. (2022, August 1). *Profielkeuze in havo en vwo*. https://www.onderwijsconsument.nl/profielkeuze-in-havo-en-vwo/

Snippe, M. (2021, February 3). *Spijt van de profielkeuze*. https://didactiefonline.nl/blog/vriend-en-vijand/spijt-van-de-profielkeuze

Spandaw, J. (2008). Wiskunde in de betaprofielen. *Nieuw Archief Voor Wiskunde*, *9*(1), 72–75.

Statistisches Bundesamt. (2023, January 23). *6.5% fewer students starting a STEM course in the academic year of 2021*. https://www.destatis.de/EN/Press/2023/01/PE23_N004_213.html

Statology. (2021). *Cohen's Kappa statistric: definition & example*. https://www.statology.org/cohens-kappa-statistic/

Stichting Technasium. (n.d.). *Levensecht bètatechnisch onderwijs*. Retrieved August 10, 2023, from https://www.technasium.nl/

Streefkerk, R. (2022, December 19). *Transcribing an interview | 5 Steps & Transcription Software*. https://www.scribbr.com/methodology/transcribe-interview/

Techniekpact. (2022, February 17). *Aantal openstaande vacatures naar beroeprsklasse*. https://www.techniekpact.nl/nieuws/aantal-openstaande-vacatures-naar-beroepsklasse

TechniekPact. (2022, April 28). *Monitor Havo/Vwo*. https://www.techniekpact.nl/monitor-techniekpact/monitor/havovwo#grafiek22

Tey, T. C. Y., Moses, P., & Cheah, P. K. (2020). Teacher, parental and friend influences on STEM interest and career choice intention. *Issues in Educational Research*, *30*(4), 1558–1575.

Universiteit Utrecht. (2022, July). *Freudenthal Institute Data Management Protocol*. https://www.uu.nl/sites/default/files/FI%20Data%20Management%20Protocol-July2022.pdf

U.S. Bureau of Labor Statistics. (2022, September 22). *Employment in STEM occupations*. https://www.bls.gov/emp/tables/stem-employment.htm

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education*, *41*(2), 150–164. https://doi.org/10.1080/09500693.2018.1540897

van Langen, A., & Meelissen, M. (2019). *De lekkende bèta/technische pijpleiding en hoe deze te repareren*.

Vathorst College. (n.d.). *Wereldgericht onderwijs*. Retrieved February 10, 2023, from https://vathorstcollege.nl/onderwijs/

Wang, M.-T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental Review*, *33*(4), 304–340. https://doi.org/10.1016/j.dr.2013.08.001

Xue, Y., & Larson, R. (2015). STEM crisis or STEM surplus? Yes and yes. *Monthly Labor Review*. https://doi.org/10.21916/mlr.2015.14

Zilberman, A., & Ice, L. (2021, January). Why computer occupations are behind strong STEM employment growth in the 2019–29 decade. *Beyond the Numbers*, 2.

Appendix A
Informed consent

Je neemt geheel vrijwillig en vrijblijvend aan dit onderzoek deel. Je kunt op elk moment je deelname beëindigen of weigeren. Hiervoor hoef je geen enkele reden op te geven. Het heeft bovendien geen enkel nadelig gevolg. We bewaren alle gegevens vertrouwelijk. Jouw identiteit en de onderzoeksgegevens bewaren we altijd gescheiden en alleen de hoofdonderzoeker heeft de sleutel om ze aan elkaar te koppelen. De gegevens worden geanonimiseerd zodat ze op geen enkele wijze op jou terug te leiden zijn. Ze worden gebruikt in een (wetenschappelijke) publicatie over het onderzoek. Als je zorgen hebt over de manier waarop met privacy wordt omgegaan, kun je dit melden via privacy@uu.nl. Willen jullie beiden je naam zeggen en zeggen of je hiervoor toestemming geeft of niet?

Appendix B
Interview questions in Dutch

Dean questions

1. Is het laten vallen van bètavakken iets waar jullie veel mee bezig zijn?
2. Welke redenen noemen leerlingen in jullie ervaring voor het laten vallen van bètavakken?
3. Is dat bij andere vakken dan bètavakken anders?
4. Waarom is het volgens jullie belangrijk om te weten waarom leerlingen bètavakken laten vallen? Wat is het probleem?
5. Wat denken jullie zelf over oplossingen voor dit probleem?
6. Wat hebben jullie al geprobeerd om dezer situatie te verbeteren?
7. Stel je voor dat jullie leerlingen zouden interviewen, welke vragen zou je dan zeker willen stellen?
8. Laatste vraag: zijn er nog andere dingen die jullie kwijt willen over redenen waarom leerlingen bètavakken laten vallen
9. Opvolgvragen: waarom, leg eens uit, geef eens een voorbeeld

Student questions

1. (Opening) Hoe bevalt het jullie in de vierde klas?
2. Hoe kijk je nu terug op de profielkeuze vorig jaar?
3. Door wie ben je ondersteund tijdens het maken van de profielkeuze?
4. Was die ondersteuning voldoende?
5. Waarom heb je een extra vak gekozen?
6. Waarom heb je voor [het betreffende vak] gekozen?
7. Waarom heb je [het betreffende vak] uiteindelijk laten vallen?
8. Zijn er nog andere dingen die je wilt zeggen over de profielkeuze en de keuze van de vakken binnen een profiel?

Appendix C
Codebook

Students' quotes			
Category	**Subcategory**	**Description**	**Typical quote**
SCC	**Tutor**	How students have perceived the support of their tutor when choosing the subjects during the SCC	"For every subject, there was a kind of presentation about what we would do next year. And then, we would do the SCC and then we received support from or tutor or something"
	Teachers	How students have perceived the support of their teachers when choosing the subjects during the SCC	"[the teachers told] us: 'do not choose a subject you enjoy, but choose a subject you think you need' or something like that"
	Parents	How students have perceived the support of their parents when choosing the subjects during the SCC	"My parents did help me with deciding which subjects are important and which subjects fit me…"
	Peers	How students have perceived the support of their peers when choosing the subjects during the SCC. This can also be an informal converstation about the SCC	[I have] talked [about my SCC] a lot [with my] friends. [We asked each other:] 'what are you going to do?' or 'how are you prepared [for the SCC]?'"
Choosing a subject	**Intrinsic**	Intrinsic reasons of students to choose a subject e.g. enjoying the subject, or finding the subject interesting	"I chose to enrol [in biology] because I enjoyed the subject"
	Level of difficulty/competence	Reasons of students that have to do with the perceived level of difficulty of the subject, or students' own	"Biology is easy"

		perceived level of competence	
	Identified	Identified reasons of students are knowing they need a specific subject cluster or subject to be able to work in the field they want to work in, be able to enrol in a specific study or to go from havo to vwo	"[I also chose biology] to be able to do the tertiary education [I wanted to]"
Discontinuing a subject	**Intrinsic**	Intrinsic reasons of students to choose a subject e.g. not enjoying the subject	"I did not enjoy [biology]"
	Level of difficulty/competence	Reasons of students that have to do with the perceived level of difficulty of the subject, or students' own perceived level of competence	"[I] can't do [biology] and it costs too much time"
	Identified	Identified reasons of students are knowing they do not need a specific subject cluster or subject anymore because they don't want to work in the field they wanted to work in, or don't want to enrol in a specific study or to go from havo to vwo anymore	"[I discovered the tertiary education I wanted to do] was at a university and I [can't enrol in a university course] because I do havo"
Other	-		

Students' advice

Category	Subcategory	Description	Typical quote
Practise	-	Students want more practise with some lessons or exercises from 10th grade	"Maybe each teacher of each subject can teach us some lessons so you have an idea of next year"
Information	-	Students want more information about the SCC and how subjects are teached in the 10th grade.	"[The teachers] should make some kind of scheme so we can see what we have to do in the next year"
Time	-	Students want more time to make a SCC	"The SCC had to be completed in one week without knowing something about it, [I wish the window of choosing was longer]"

Deans' quotes

Category	Subcategory	Description	Typical quote
Solutions for discontinuing STEM subjects	-	Solutions for discontinuing STEM subjects after electing them. This category includes both solutions that have been recently implemented and solutions that have yet to be implemented.	"[We want to] to determine in 9th grade if [students] are able to succeed in a subject they chose"
Choosing a STEM subject	-	Deans' perception of reasons for students to choose a STEM subject	"We have come at a turning point. [Students] think 'I can choose an additional STEM subject, because I can always discontinue it.'"
Discontinuing a STEM subject	**Level of difficulty/competence**	Deans' perception of reasons for students discontinuing STEM subjects that have to do with the perceived level of difficulty of the subject, or students' competence	"[…] physics is often too hard for [the students], too difficult"
	Miscommunication	Deans' perception of reasons for students discontinuing	"[…] the communication [about the SCC] is not unambiguously anymore. […] us deans can

	STEM subjects that have to do with miscommunication amongst all parties (teachers, tutors, deans and students)	approach teachers with less ease [compared to before]"
Corona	Deans' perception of reasons for students discontinuing STEM subjects that have to do with corona	"I have to say, after corona, more students [have discontinued a subject] compared to before."