Triggering the Technicians

The connection between secondary-school Technasium education and Industrial Design Engineering at university (Delft)

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Contents

1. Abstract 4
2. Introduction 5
3. Context 6
   3.1. Technasium 6
   3.2. Industrial Design Engineering 7
4. Theoretical framework 8
   4.1. Theory of planned behavior 8
   4.2. O&O and study choice 11
   4.3. Study choice 11
   4.4. Boys and girls 12
   4.5. Student flow from secondary school to TU Delft 15
5. Aim of this study 15
6. Research questions 15
7. Method 16
   7.1. Research context 16
   7.2. Participants 16
   7.3. Recruitment 17
   7.4. Research design 17
   7.5. Study 1—construction of the interview 18
      7.5.1. Influences of O&O on study choice 18
   7.6. Study 2 - Construction of the interview 22
   7.7. Reliability and validity 24
   7.8. Ethics 24
8. Results 25
   8.1. Study 1 25
      8.1.1. Chosen studies (attitude) 25
      8.1.2. Choices of students in doubt (attitude) 26
      8.1.3. What influences the study choices of Technasium students? 27
   8.2. Study 2 31
      8.2.1. Choice of IDE 31
      8.2.2. Expectations 32
      8.2.3. Reality of IDE 33
      8.2.4. Preparation 35
      8.2.5. How difficult or easy is IDE? 36
      8.2.6. Important skills at IDE 38

9. Conclusion 39
9.1. Influences of O&O 39
9.2. First-year experience of IDE 40
9.3. General summary 40
10. Discussion and recommendations 41
10.1. Study choice 42
10.2. Influences on study choice 43
10.3. First-year IDE 44
10.4. Difference between boys and girls 45
10.5. Choosing for a gap year 45
11. References 46
12. Appendix A learning objectives IDE 49
Mens en product 49
PO1 49
Design X 50
Product in werking 50
Business Culture and Technology 51
PO2 51
Research and Design 52
Appendix B. Interview protocol O&O students. 53
Appendix C. Interview protocol first year students IDE 54
Appendix D. Word web study 1 55
Appendix E. Word web study 2 56

1. Abstract

In the Netherlands, more employees with skills in science, technology, engineering and mathematics (STEM) are needed to overcome the shortage of sufficiently trained staff in the technology sector. To address this problem a special educational program called Technasium, consisting of a Research and Design (O&O) course supplementing normal pre-college or pre-university education, was recently introduced in a number of secondary schools. The purpose of the course is to arouse students' interests in STEM education. A relatively large number of students who complete the O&O course go on to apply for an Industrial Design Engineering (IDE) course. The research for this thesis was conducted to gain insight into how the O&O course stimulates interest in STEM among students, and how it connects with the IDE course at Delft University of Technology (TU Delft). Interviews were conducted with secondary-school Technasium students to explore the impact of O&O on their subsequent study choices. The interview sample group of scholars attending their first year of IDE studies at TU Delft consisted of both ex-Technasium students and students who did not follow the Technasium program while at secondary school. This mixture served to highlight the differences in first-year experiences. Results showed that the O&O course influences secondary-school students in choices relating to STEM and medical studies. These insights confirm the thoughts from the Technasium foundation about O&O influencing students in their study choice towards STEM and medical studies. These results can be used to inform potential Technasium students. Compared to regular students, ex-Technasium students experienced advantages in first-year IDE owing to their greater familiarity with recurring creative and design processes and because of experience matured in preparing presentations and working in teams. However, these advantages partly depended on which secondary school the students had attended and the subjects provided in their O&O course. These benefits are experienced as negative in some cases. Working on fictitious project in first-year IDE felt like a step back for a number of ex-Technasium students. These new insights tell us a better transition from Technasium to IDE is not guaranteed. However, because there is just a small number of Technasium students choosing for IDE, this is not a major concern for TU Delft.

2. Introduction

Science, technology, engineering, and mathematics education is attracting more attention in the Netherlands. A study by Nationaal Techniekpact 2020 (2013) suggests that a large group of employees in the STEM business community will retire over the next few years—between now and 2020 an estimated 30,000 jobs are expected to become vacant annually, and there will not be enough new staff to fill them. By increasing the number of STEM students, this shortage may be managed. Around 25% of pre-university (VWO) student graduates (±6000 students) currently apply for a STEM bachelor's course at a university in the Netherlands each year (Instroom nieuwe bachelorstudenten, 2016).

In response to the demand for more STEM students, a Technasium program has been implemented in several Dutch secondary schools over the past 12 years. The program is intended as preparation for studies and employment in STEM fields, and as well as providing opportunities for practical cooperation with companies in relevant industries, it involves students in targeted educational projects relating to topics in the sector (Bruning, 2014). Currently, it focuses on preparing pre-college (HAVO) and VWO secondary-school students for STEM education.

In addition to the normal HAVO and VWO secondary-school courses, the Technasium program includes an extra course called O&O—an abbreviation for "Onderzoek & Ontwerpen" (Research and Design). It is included in the curriculum from first through fifth grade (comparable to grades seven through 11 in the US school system) for HAVO and through sixth grade (comparable to 12th grade in the US school system) for VWO students. During these five or six years, students learn to work in teams on projects that can be either fictitious or commissioned by external parties (Wat is Technasium?, n.d.). Technasium Nederland (2014) shows that the two study paths most commonly chosen by Technasium students are Medicine and IDE, which are respectively medical and STEM studies. Just as the O&O course is thought to help students prepare for STEM education in areas such as applied physics, mechanical engineering or biomedical engineering, it can also be seen as preparation for IDE. A smooth connection between the STEM-targeted program at secondary school and later university studies is naturally desirable, and Technasium students are expected to undergo this transition better, especially in the case of interdisciplinary STEM education (Bruning, H., 2014). However, because of Technasium's relatively short existence, little is actually known about how such students transition to IDE at TU Delft and to university in general. This study therefore focuses on the passage from one academic institution to the other, to investigate the ways in which the process succeeds and to identify possible flaws. Both the Technasium foundation and TU Delft may find this information useful in forming or reforming curricula, as well as in helping future students in their choices.

My own IDE studies for a bachelor's degree at TU Delft have fostered my interest in design and engineering. I became interested in this area of research after reading the O&O guide published by Bruning in 2014. The guide features the learning objectives students need to master, and I noticed similarities between these goals and my own experiences on the IDE course at TU Delft. The similarity in learning aims suggests an IDE course would appeal to Technasium students deciding how to further their studies.

Effective training during the Technasium program could produce students with more STEM skills than non-Technasium students. The question remains as to whether the O&O course can be beneficial for studying at TU Delft, and how O&O influences students in their study choices. If students completing the program progress more easily to STEM universities, this factor could play an important role in the way pupils and their parents choose a secondary school.

This study attempts to answer the main research question: How do first-year students who completed the O&O course experience the transition to a STEM course (IDE at TU Delft), in comparison with students who did not follow the O&O course? The comparison is made by conducting individual interviews with students from both groups. In addition to answering the research question, this thesis also examines whether the O&O course influences students' choice of study. First, the contexts of Technasium and IDE at TU Delft are described. Next, existing theory about study choice and human behavior is outlined in a theoretical framework used later to construct a questionnaire. The questionnaire format derives from a framework created by Kemper, van Hoof, Visser, and de Jong (2007), which in turn was based on Ajzen's theory of planned behavior (1991). The interviews were conducted using focus groups. Finally, data from the interviews is analyzed to gain insight into the study choices of O&O students and their experiences during the transition to IDE at TU Delft.

3. Context

This chapter describes the basic concept behind Technasium and the skills-based approach the O&O course promotes. It goes on to outline various facets of the IDE study program, to form a basis for comparison between the two courses.

3.1. Technasium

Technasium is a collective name for an education program currently implemented in 92 secondary schools in the Netherlands (Wat is Technasium?, n.d). Students have to apply to follow the course at the moment of entering their secondary school of choice. The difference between regular HAVO or VWO education and the Technasium program lies in an extra course called O&O. Dutch HAVO and VWO secondary schools are divided into two phases. The first phase corresponds with grades one through three, while the second phase includes the fourth and fifth grades for HAVO, and the fourth,

fifth, and sixth grades for VWO. After the first three years, both HAVO and VWO students have to choose whether to continue the O&O course in the second phase of their secondary-school careers. Bruning (2014) demonstrates that the second phases of HAVO and VWO consist of a total of 3,200 and 4,800 hours of study respectively, and cover all the activities required for a student to successfully complete the courses, including 360 hours of O&O study for second-phase HAVO and 440 study hours for second-phase VWO. Because O&O is an additional course within the same overall number of study hours, the hours it occupies are deducted from other courses. Students finish the O&O course with a large experiment called the 'Meesterproef'. During this final project, the students choose their own group and subject and perform the experiment during their last year (fifth-grade HAVO or sixth-grade VWO). If they pass the HAVO or VWO exams and finish the O&O course they receive a Technasium certificate and a HAVO or VWO diploma.

The Technasium O&O course educates students to master learning goals in the following four domains (Bruning, 2014):

1. General skills such as communication, working in groups, using scientific instruments and researching.
2. Ways of thinking and methods of research and design. In this domain students further their skills in project work, communication with clients and knowledge about research and design.
3. Core qualities. These are the areas of competence the students should become acquainted with, developing the right attitude to create an open mind towards learning and self-reflection.
4. STEM domains. In this final domain, students have to choose two (for HAVO) or three (for VWO) STEM directions to show the skills they master. The directions to choose from are technological innovations in science, nature, mobility and space, nutrition, market and money, health, and lifestyle and design.

3.2. Industrial Design Engineering

The IDE study course at TU Delft consists of a three-year bachelor's degree program and a two-year master's degree. During the bachelor's program, students are required to develop a broad view of the design profession by investigating different perspectives of design engineering. The IDE program defines more specific learning objectives compared to the O&O domains explored during Technasium studies. In the first year of IDE at TU Delft, students are required to pass eight courses involving varying aspects of practical design, mathematics and physics, ergonomics, business and culture, aesthetics and research (Industrieel Ontwerpen, 2016). Every course in the IDE program has specific learning objectives tailored to the subject requirements (see Appendix A, Learning objectives per IDE course). For example, the learning objectives for a first-year course called Design Experience are

"Form integration:

The student is capable of integrating shapes with different qualities in terms of form language.

Color:

The student is capable of analyzing color in its dimensional qualities, and can make balanced color suggestions for products on the basis of valid color combinations.''

4. Theoretical framework

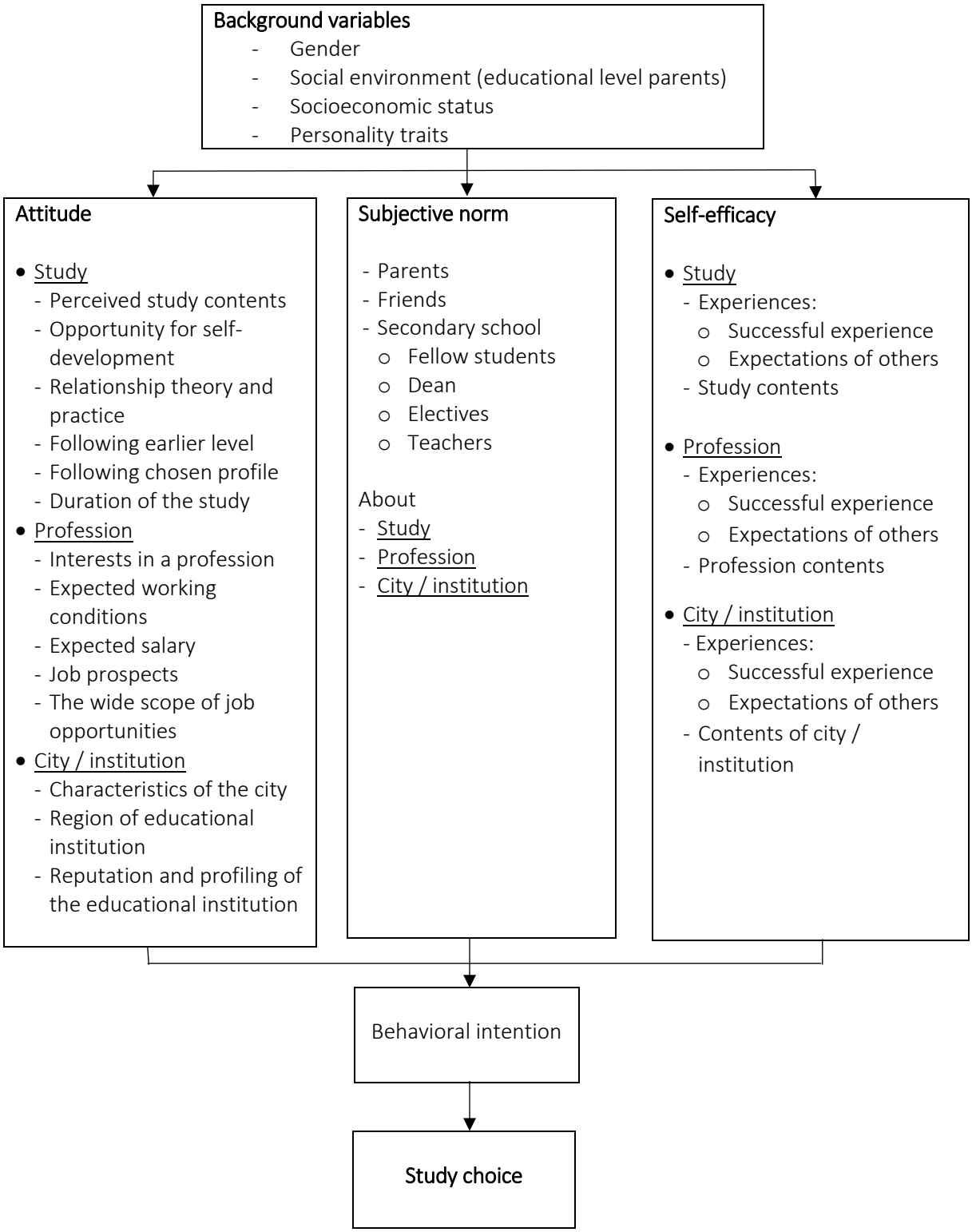
4.1. Theory of planned behavior

Choosing a degree is not usually something that is done overnight, and as mentioned previously, different factors can influence the final decision. Kemper et al. (2007) used the theory of planned behavior (Ajzen, 1991) to create a framework mapping important factors in study choice. This choice could be seen as a form of human social behavior. Ajzen (1991) describes a conceptual framework which can be used to get insight in this behavior. Human social behavior is defined as the intention of a person to actually behave in a certain way. The intention is seen as the key factor for this behavior (Ajzen, 1991). In the theory of planned behavior, Ajzen (1991) demonstrates that intentions are influenced by three determinants: attitude, subjective norm and perceived behavioral control (which is compatible with the term self-efficacy). These three determinants are reflected in the study-choice framework by Kemper et al. (2007). Important factors in study choice, as suggested in the article by Kemper et al. (2007), are the images students form about a study, institution or profession (attitude), social environment including factors such as parents, friends and school (subjective norm) and positive experiences within school courses (self-efficacy). Along with the three determinants of behavioral intentions, Kemper et al. (2007) also discuss background variables. These variables are defined as gender, social environment, socioeconomic status and personality traits. Table 1 shows the framework by Kemper et al. (2007), with content translated from Dutch to English. A limitation of this framework, however, is that it disregards how students arrive at the studies to consider in their study choice. Students could be interested in a certain study long before secundary school.

There are several variables of interest in the choice of tertiary education. In this study, however, I use a qualitative approach to see how students undergo this process in the specific case of the Technasium program. The framework by Kemper et al. (2007) serves as a foundation for the interviews conducted to explore how Technasium students experience possible influences of the O&O course in their later study choices. The variables (background variables, attitude, subjective norm and self-efficacy) appear in the questionnaire as the subjects of interview questions. Very little research is conducted using the framework by Kemper et al. (2007), which was designed for study counselors to shed light on the process of study choice. In this research, I apply the framework to the specific

context of the Technasium program in secondary education, to see whether parts of it are reflected in the students' experiences. On the basis of the outcomes, I then draw conclusions as to whether any particular subject can be identified as the most important study subject of choice, or whether a combination of factors determines study choice for this group of Technasium students.

Table 1. Study-choice determinants classified using theory of planned behavior determinants.



Adapted from ''Studiekeuze in kaart gebracht: gedragsdeterminanten van scholieren bij het kiezen van een vervolgopleiding'', by Kemper et al., 2007, Tijdschrift voor Hoger Onderwijs, 25 (4); p. 274.

4.2. O&O and study choice

By stimulating personal-identity development through self-reflection reports, the O&O course has the potential to help improve the transition from secondary school to college or university (Bruning, 2014). Research has shown that students following the Technasium program at secondary school, especially in the second-phase years, feel empowered during the O&O course (Prins, Vos & Pilot, 2011). Empowerment in this case means the creation of intrinsic motivation for students by creating a working environment that contributes to positive self-efficacy (Block, 1987). One cause for this high degree of empowerment—especially in the students' final three years—stems from the opportunity to choose O&O projects that suit their own interests. Comparing this with the framework from Kemper et al. (2007), high empowerment could be seen as creating a positive attitude towards a study by addressing own interests. Also a positive self-efficacy, that is adopted in the determinants from the framework of Kemper et al. (2007), recurs in the term empowerment. Prins et al. (2011) also explored the different STEM studies students were provided with on the O&O course. Using a Likert-scale questionnaire, they concluded that these students felt O&O helped them achieve a broader view of STEM studies. This broader view could be seen as a positive attitude towards different professions in the framework from Kemper et al. (2007). The relationship between the mechanisms and factors studied and the subsequent study choice are also expected to be discussed by the participants in the research for this thesis. Self-efficacy, subjective norms and attitudes have been shown to play a role in the study selection process (Kemper et al., 2007), but whether students experience this in the same way in their transition from a Technasium secondary school to IDE or whether additional factors are important, remains to be seen.

4.3. Study choice

In examining the transition process from a Technasium secondary school to the IDE course at TU Delft, choice of degree is crucial. Many studies have explored this process, mainly using quantitative data. Different factors may contribute to the development of a positive academic attitude and final study choices. According to Cabrera, A. F. and La Nasa, S. M. (2000), the process of selecting a college and a field of university study can be divided into three stages which occur from first through sixth grade at secondary school (seventh through 12th grade in the American school system). These stages are described as: (1) Predispositions (grades one through three), (2) Search (grades four through six), and (3) Choice (grades five through six). In all of these stages parents play a key role in forming ideas for study choice. Moreover, the realization of the importance of pursuing higher education and doing extracurricular activities covers a large part of this choice (Cabrera & La Nasa, 2000). Factors such as family focus and priorities, perception of the level of STEM careers by the students, and interests the students have will spur or inhibit the interest in STEM studies (Aschbacher, Li, & Roth, 2010). School

courses and teaching methods are also important for maintaining or developing an interest in a given study direction and in subsequent study choice (Watkins & Mazur, 2013).

Because it involves group work rather than individual learning, the O&O course could be seen as a departure from the normal secondary-school curriculum. Different ways of learning can expose students to new experiences. Whether the experience is positive or negative, a single occasion may be sufficient to confirm—or discourage—a student's study choice. Lichtenstein, Loshbaugh, Claar, Bailey and Sheppard (2007) showed, for example, that a positive experience in a specific pre-engineering course could cause a student to stop doubting and choose in favor of an engineering degree. Conversely, a student experiencing poor teaching in a pre-engineering course could migrate in a different direction instead. Technasium students might be influenced by the O&O course because of the different methods used compared to other courses. Teaching with peer instruction methods, for example, and working in groups, as in the O&O course, can enhance students' performances (Watkins & Mazur, 2013). According to Driver, Newton and Osborne (2000), students gain the ability to form scientific arguments during discussions in group activities, and acquiring this skill may increase the chances of pursuing a career in a similar field of study. Stronger self-efficacy on the part of students would lead to more rationally made choices (Katerina Argyropoulou., n.d), which usually fits the demands of decision-making better (Sidiropoulou and Dimakakou, 1993).

Apart from providing study guidance, the secondary schools themselves could also help students in their transition to university. Preparations could be made to make the process smoother. Secondary-school students often have difficulties forming specific expectations and predictions about their experiences after the transition (Briggs, Clark & Hall, 2009). Briggs et al. (2009) suggest preparing students early on and providing them with opportunities to visit universities, to allow them to establish a clear image of what it will be like to study there. The transition process could also be made less difficult as a result of students' own personal development (Berzonsky & Kuk, 2000).

4.4. Boys and girls

One factor that may well shape a student's decision-making process is gender (Kemper et al., 2007). Van der Veen and Blume (2015), showed a difference between girls and boys who applied to attend a university of technology after completing the Technasium program, with less girls opting for a STEM study than boys. In general, girls are less interested in physical sciences than boys (Siann & Callaghan, 2001), and this suggests more boys go on to choose studies or a career in technology than girls. Earlier studies (Sjøberg & Schreiner, 2010) show that girls tend to prefer health care and working with people more than boys, who would rather work with their hands and solve problems with technology. The male-dominated image linked to technological practices furthers the under-representation of girls in STEM education (Siann & Callaghan, 2001). Men are overrepresented in the sector, and women

consider this a barrier to applying for STEM education (Siann & Callaghan, 2001). A look at the numbers from IDE at TU Delft reveals an almost equal division between men and women taking the IDE and Architecture (BK) courses in 2014-2015. This ratio changes in several other studies at TU Delft where women are underrepresented. For example, 364 men entered the first year of Applied Physics (TNW), compared to 153 women. The studies where women are underrepresented could be described as the more technological studies compared to IDE and BK.

In their previously mentioned 2015 study, Van der Veen & Blume found that around 34% of Technasium students were girls, but that only a small number were found in the engineering programs of the University of Twente (UT). A reason for this outcome was not identified, and will be very hard to find. There are a lot of variables that could act as a positive or negative influencer for girls choosing for STEM education. Gathering qualitative data to elicit possible reasons for this gender difference would be very useful to gain more insight into students' study choices. Table 2 shows the intake of students at TU Delft in the 2014-2015 academic year.

Table 2. Inflow of students at TU Delft 2014-2015.

TU Delft first-year students on December 1st of academic year 2014-2015										
	Total	Gender		Nationality		Education				
Inflow bachelor, master and transition students										
Faculty		Men	Women	Foreign	Dutch	VWO	HBO	WO	International	Other
3mE	**860**	709	151	171	689	602	47	26	181	4
BK	**451**	207	244	189	262	232	4	16	195	4
CiTG	**706**	518	188	184	522	425	43	31	205	2
EWI	**589**	481	108	169	420	366	21	16	182	4
IDE	**327**	166	161	41	286	268	3	8	47	1
LR	**543**	469	74	266	277	221	12	6	302	2
TBM	**252**	150	102	63	189	158	17	9	64	4
TNW	**517**	364	153	106	411	361	12	20	122	2
Total inflow bachelor, master and transition students	**4245**	**3064**	**1181**	**1189**	**3056**	**2633**	**159**	**132**	**1298**	**23**

4.5. Student flow from secondary school to TU Delft

Earlier research (Van der Veen & Blume, 2015) uses quantitative data to investigate the stream from Technasium schools around Twente to UT. A large number of Technasium students (57%) preferred design and construction-based engineering studies such as IDE and Mechanical Engineering. Drop-out numbers were checked at the university for both ex-Technasium students and students who did not participate in a Technasium program. Interestingly, drop-out numbers were greater in the ex-Technasium group compared to all science and engineering students. Moreover, grades in mathematic exams of the Technasium group were lower (6.3 vs. 7.1 out of 10). This could indicate a poor connection between the Technasium program and UT, as compared with VWO students who did not follow the Technasium program. However, the number of ex-Technasium students included in this research was limited, and a strong conclusion was therefore hard to reach. Except for the results from Van der Veen & Blume, 2015, little is known about the transition of Technasium students from secondary school to college or university. By researching the transition of such students to the IDE course at TU Delft, this study aims to shed additional light on the subject.

5. Aim of this study

This study examines how the Technasium O&O course conducted in Dutch secondary schools connects with the IDE course at TU Delft. It investigates what kind of influence the O&O course has on students who follow it and how they experience their first year at IDE compared to students who do not attend the Technasium program. The research outcomes advance understanding of the possible contribution of the Technasium program to the transition process. This study aimed to get insight in how the influences from O&O on study choice could possibly be an advantage in the transition to IDE. A number of sub questions support exploration of the main research question.

6. Research questions

1. How do first-year students who completed the O&O course experience the transition to a STEM degree course (IDE at TU Delft), in comparison with students who did not follow the O&O course?
2. How does the O&O course at secondary school influence the choice of a (STEM) study program at university?
    - 2.1. How are students' interests influenced by O&O?
    - 2.2. How is study choice influenced by following O&O at secondary school?
    - 2.3. What are the differences in study choice between girls and boys?

7. Method

7.1. Research context

The first part of this study (Study 1) was conducted at four Technasium secondary schools in the Netherlands: Keizer Karel College in Amstelveen, Calland Lyceum in Amsterdam, Gerrit Rietveld College in Utrecht and Libanon Lyceum in Rotterdam (Scholen, n.d.). The schools were selected on the basis of their ability to cooperate within the available time slot for this research. All schools are Technasium schools that teach O&O as a course. The second part of the study (Study 2) was carried out at the IDE faculty at TU Delft.

7.2. Participants

The research was designed to explore students' ideas and experiences. In Study 1, students at four Technasium secondary schools were therefore interviewed. The interviews were held in the form of group discussions to find out which subjects recurred frequently in these conversations. These group interviews also made it possible for participants to discuss the questions amongst each other, and revealed the in-depth thoughts of the participants more clearly than a survey would have done. Eleven groups of three to five students were formed, thereby forming a total of 42 students from Technasium secondary schools that were interviewed.

The aim was to interview only students in graduating grades at the secondary schools (sixth grade VWO). Unfortunately, some of the students could not participate because of a conflict in schedule with their final exams. The interviews were therefore conducted with students from two graduation grades and two fifth grades instead. Because fifth-grade students lack one school year of exploring options and making their study choice compared to sixth-graders, this may have led to different results in the numbers of students that had already made their study choice. However, according to Cabrera and La Nasa (2000), the decision-making process already starts in the fifth grade and extends to the sixth grade. The difference between the fifth and sixth grade has been taken into account in the interpretation of the results.

Table 3 illustrates the Study 1 sample size.

Table 3. Study 1 sample size.

Secondary school	Calandlyceum Amsterdam	Gerrit Rietveld College Utrecht	Keizer Karel College Amstelveen	Libanon Lyceum Rotterdam	**Total**
Number of interviewees	12	8	9	13	**42**
Number of boys	4 Boys	7 Boys	5 Boys	5 Boys	**21 Boys**
Number of girls	8 Girls	1 Girl	4 Girls	8 Girls	**21 Girls**
Grade	5th-grade VWO	6th-grade VWO	5th-grade VWO	6th-grade VWO	

Note: This table shows the division of participants for the sample group from study 1.

On the university IDE-course side, two groups were formed for Study 2. One group consisted of eight first-year students that had followed the Technasium program at secondary school, while the other group consisted of eight first-year students who had not attended the program.

7.3. Recruitment

Some problems arose during the search for these ex-Technasium students. The TU Delft IDE Faculty could not supply information about which students had attended the Technasium program before applying for IDE in the year under examination, because it would have led to a breach in privacy. The only information available—through Sylvia Walsari Wolff from Education and Student Affairs (O&S)—was that there were 12 ex-Technasium students currently following the first-year IDE course. To reach out to these students I enrolled myself in a first-year Facebook page of the IDE faculty and asked the ex-Technasium students to contact me if they wanted to take part in my research. Eight students were willing to cooperate. All students from both groups were interviewed individually in interviews lasting approximately one hour.

7.4. Research design

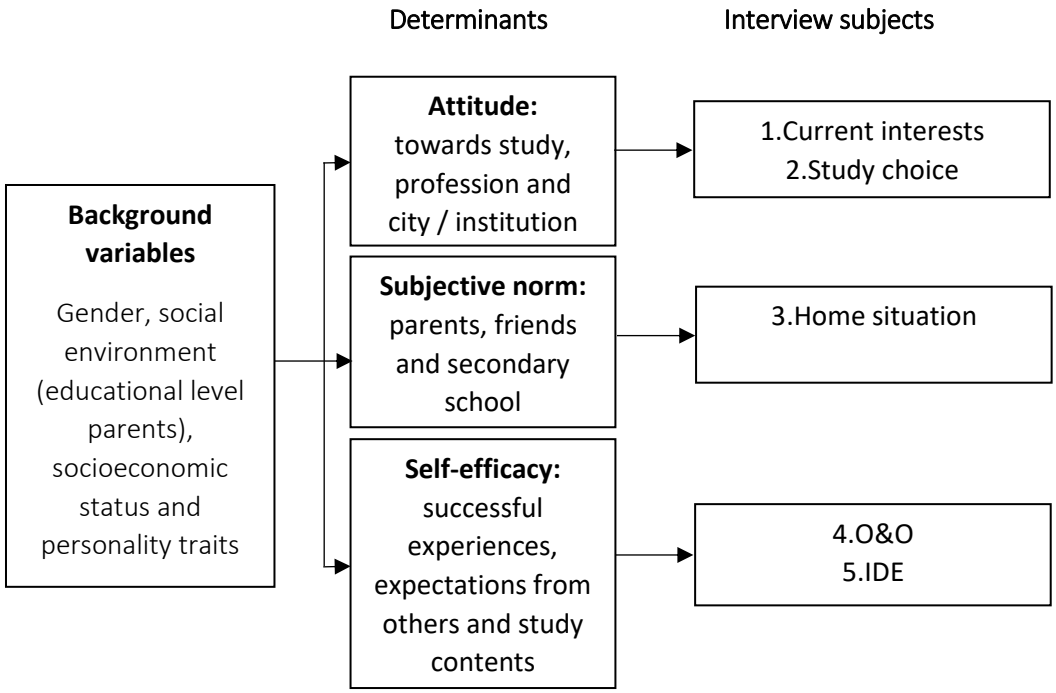
This study explores the study choices of ex-Technasium students and their experiences in the first year at TU Delft IDE. Transcribed interview recordings provided the qualitative data necessary to gain more insight into the transition process and the influence O&O has on study choice. A qualitative approach was used to obtain in-depth student responses to the research topics. Some quantitative data was also gathered to compare the numbers of the different groups of students. Because this study was performed in the Netherlands with Dutch participants, the questions were designed in Dutch by a native speaker and were answered in Dutch by the participants. The quotations used in this paper were translated from Dutch to English.

7.5. Study 1—construction of the interview

7.5.1. Influences of O&O on study choice

Small focus-group interviews were conducted with Technasium students at the four secondary schools mentioned in Section 7.1. These interviews were conducted at the schools of the participants (see Table 2. Study 1 sample size). Group interviews were held to let the participants discuss the topics together and take advantage of the synergies in focus-group discussions (Morgan, 1996). Insight into study choice and the influences on this study choice was gained using a list of questions. In constructing the interview for Study 1, the three determinants (attitude, subjective norm and self-efficacy) and background variables from the framework by Kemper et al. (2007) were used as a foundation for the list of questions. The questions about study choice were partly adopted from the interview ''Vragenlijst attitude & studiekeuze technasiumleerlingen" (Van der Neut, 2013), and partly my own. The list of questions contained five subjects matching the three determinants from the framework by Kemper et al. (2007): (1) Current interests, (2) Study choice, (3) Home situation, (4) O&O and (5) IDE. These subjects are in line with the determinants from Kemper et al (2007) mentioned previously, as can be seen in Table 4.

Table 4. Construction of the Study 1 interview showing the influences on study choices.



Study choice is often influenced by family and the student's own interests (Aschbacher et al., 2010). Exploration of this subject was designed to provide further insight into the effect students' current interests and home situations had on their study choice (for the list of main questions translated into English see Table 5. Main interview questions O&O students. For the complete interview protocol in Dutch see Appendix B.)

Before conducting the interviews, the list of questions was reviewed by my supervisors Prof. dr. M. de Vries and T.E. Vossen MSc. A pilot interview was conducted to see whether the interviewees would be able to understand the questions and whether they were able to answer them properly in the set time. The time planning of the interview was found to be accurate and the questions stimulated sufficient discussion within the group.

To elicit students' opinions, probing questions were asked in between the set questions. The interviews were recorded with a memo audio recorder. After transcribing the recorded interviews, the transcriptions were coded using two coding steps: open and Axial (Creswell, 2006 ; Bryman, 2012). By first reading through the transcriptions and coding the sentences in the transcriptions, clusters of codes came up that could fit the interview subjects in Table 4. These clusters, made using word webs (for an example, see Appendix D. Word web Study 1), formed categories that are discussed in the results chapter.

Table 5. Main interview questions for O&O students

1. Current interests (5-10 min) - What are your current interests, what do you like doing? (e.g., hobbies or sports) - In your opinion what influenced the development of these interests? (e.g., friends, family, school, media) - With whom do you share these interests?
2. Study choice (10 min) - What are you going to do after secondary school? - Why do you want to do this study? - What had the most influence on your study choice?
3. Home situation (5min) - What are the professions of your family members? (i.e., parents, custodian, brothers, sisters) - Do you think this influenced the development of your own interests? If so, how?
4. O&O (10 min) - Why did you choose O&O? - Did O&O play a role in your study choice? - Did your thoughts about your future change because of O&O?
5. IO (5min) - Have you ever heard of design studies? - Have you considered choosing a design study? - Would IDE, BK, Mechanical Engineering or other design studies connect with O&O?

Current interests and home situation

Students were asked about their current interests and home situation to get a general view of the possible impact of these factors on study choice. Interests can be viewed as an outcome of a learning process, and in a certain way they are related to intrinsic motivation (Schiefele, 1991). They are an important factor behind a study or career choice and are often dependent on a student's home situation (Ashbacher et al., 2010; Cabrera & La Nasa, 2000). The most important interests of the participants were elicited through open questions. The interview questions about participants' home situations reflected the subjective norm that Kemper et al. (2007) identified as an important aspect of study choice.

Study choice

Questions on Technasium students' study choices were designed to explore whether these choices were aligned with the Dutch government's intention to raise the number of employees educated in technological subjects (Nationaal Techniekpact 2020, 2013). The factors that influenced the choices, such as interests or extracurricular events, were also recorded (Cabrera & La Nasa, 2000). No mention had yet been made of the O&O course, so this aspect did not figure in students' answers. I made a distinction between the STEM, medical and non-STEM studies students discussed. How the students talk about their study choice provides insights into their attitude towards it, or maybe even towards a profession they would like to pursue in future.

O&O

In this part of the interview students were asked why they had chosen the O&O course and whether or not—and if so, how—it had influenced their subsequent study choice. The course might be seen as an extracurricular event that could affect study choice (Cabrera & La Nasa, 2000). Moreover, the O&O teaching method involving teamwork and own choice of projects might lead to the development of an extra interest in STEM-related studies (Driver et al., 2000; Watkins & Mazur, 2013). In terms of the self-efficacy determinant defined by Kemper et al. (2007), experiences during the O&O course could produce important information. Successful experiences are seen as crucial factors in forming a study choice (Kemper et al., 2007). Students' answers to these questions formed the largest segment of the interview.

IDE

Questions about this study course focused on establishing whether students were already thinking— or not thinking— about choosing IDE. The aim was to obtain comparisons between the O&O course and design studies and understand what students thought about the connection between O&O and design studies such as IDE. According to Prins et al. (2011), students following the O&O course receive a broad view of different STEM studies, and this is researched in the last part of the interview.

7.6. Study 2 - Construction of the interview

The first-year IDE student group—16 students in total—consisted of eight students who did not attend the O&O course and eight students who did follow the course. In-depth interviews were conducted with each of the 16 participants individually. A semi structured interview was designed to obtain more knowledge about how these first-year students experienced the transition from secondary school to the IDE course at TU Delft. As in Study 1, a list of key questions was interspersed with probing questions (for the main questions translated into English, see Table 6. Main interview questions for first-year IDE students. For the complete interview protocol see Appendix C). To answer the research question exploring how ex-Technasium students experienced their first year of IDE study compared to regular students, subjects such as secondary school preparation, first-year experience and confidence during the first-year IDE course were addressed. By asking about students' preparation for IDE and expectations before commencing first-year studies, the interviews investigated the possible differences in first-year experiences as a result of O&O formation—or the lack thereof—at secondary school.

To better understand how self-efficacy in design differs between the group of ex Technasium students and regular students, questions were asked to establish how closely their skills matched those required for the IDE study and what influenced the development of these skills.

To facilitate comparisons, in addition to the open-ended questions each interview topic ended with a scale question summarizing the topic into a number. For example, following the question about how students experienced the transition from secondary school to IDE, and how their preparation at secondary school helped them in this transition, the scale question was

> ''Taking all of this into account, on a scale of 1-100% how well-prepared did you feel when you started first-year IDE (where 1% means you did not feel prepared at all, and 100% means you knew exactly what you wanted and what was going to happen in this first year)? Explain why.''

All participants were asked the same questions. As in Study 1, once the interviews transcriptions had been read, sentences were coded using open and axial coding (Creswell, 2006 ; Bryman, 2012).

Categories were formed using word webs (for an example, see Appendix E. Word web Study 2). The categories are discussed in the results chapter.

Table 6. Main interview questions for first-year IDE students

1. How do students experience the IDE study course? - *What were your reasons for choosing IDE?* - What were your expectations of IDE, and your idea of design, before you started first-year IDE? - On a scale of 1-100%, how has your idea of design changed this year (where 1% means you still think the same about design as before you started first-year IDE, and 100% means your idea of design has changed totally compared to the ideas you had before first-year IDE)? Explain why.
2. Do students agree they received good preparation for IDE at secondary school? - How did you experience the transition from VWO to IDE? - Do you think courses at secondary school prepared you well enough for the IDE course? - Taking all of this second segment into account, on a scale of 1-100% how well-prepared did you feel when you started first-year IDE (where 1% means you did not feel prepared at all, and 100% means you knew exactly what you wanted and what was going to happen in this first year)? Explain why.
2. How confident are students about their skills during the IDE design course? What is their self-efficacy? - How was your experience of first-year IDE in terms of challenges, difficulty, work method? What was positive or negative? - Which skills are discussed in the IDE study? - What is your opinion of the level of the IDE course? - On a scale of 1-100%, how easy is IDE study for you (where 1% means it is impossible to finish and 100% means it is very easy to finish)? Explain why.
4. (Only for the ex-Technasium student group) On a scale of 1-100%, how strong do you think the connection is between Technasium and O&O (where 1% means there is no connection at all and 100% means there is a perfect connection between O&O and Technasium)? Explain why.

7.7. Reliability and validity

Because the research had a qualitative approach, my role as researcher was instrumental and I therefore had to act transparently. Both the study methods and my own function in the studies had to be clearly recorded and assessed so that the conditions could be reproduced if necessary. However, external reliability in qualitative research is almost impossible to achieve, and this was also true of the study at hand, which involved students' experiences rather than the exact measurement of a variable. As Bryman (2012) suggests in his book, to achieve external reliability in qualitative research, the researcher conducting the research should adopt a similar social role in the research. This is very difficult in qualitative interviews such as those performed in this study. Probing questions can differ according to how the participants first answer the general questions, and they also depend on the thoughts of the interviewer.

Coding the transcriptions of the interviews could yield different interpretations. To reduce the risk of misinterpretation, the code clusters and subjects extracted from the clusters through my interpretations were peer debriefed by my supervisor Tessa Vossen. First, Ms Vossen read the transcripts of the interviews and listed important words or sentences. These codes were then clustered into overarching topics. Next, we both wrote down the clusters from the transcribed interviews and compared our lists. The degree of agreement indicated that my interpretations were sufficiently objective. With this method, internal reliability was taken into account.

External validity refers to the degree to which findings can be generalized across social settings (Bryman, 2012). The limited size of the sample used in this research makes it impossible to extrapolate accurately. The aim was to debate the topic in a way that resembled a real-life discussion. Explorative research explored participants' opinions and the issues surrounding the subject.

7.8. Ethics

An important part of social research concerns ethics. To comply with the code of conducts of TU Delft, the Dutch code of conduct for Science is used (Vereniging van Universiteiten (VSNU), 2014). In this study students had to be informed beforehand what participation involved. Before the interviews, they were asked to agree or disagree to take part in a recorded interview which would subsequently be transcribed and coded. Once they had agreed, the recorder was switched on and the same question was repeated; in this way the recordings provided evidence of the agreement.

To ensure spontaneous discussion it was important for all participants to feel comfortable and for no harm—either physical or emotional—to be inflicted on them in any way. Physical harm was not an issue in this particular case, but emotional harm was something to be held in consideration. The interview questions were designed not to invade participants' privacy, and this was especially

important in group discussions involving participants who might later come into contact with one another at school.

Another important part of the privacy issue in social research is the way data are protected. The data collected in this study consisted of voice-recorded interviews and transcriptions of the interviews. In the transcriptions, no names were used. Instead, names were recorded as the gender of the participant followed by a letter. The recorded interviews were saved on my own computer and secured with a password restricting access. All raw date is available for reanalysis on request, and should be for a minimum of 10 years. Using documented folders, this data can be transferred in a minimum amount of time.

8. Results

8.1. Study 1

From the transcriptions, clusters of codes were first formed in a word-web showing notable categories relating to the interests and study choice—as well as the influences of O&O on study choice—of Technasium students. Recurring subjects mentioned in the interviews were (a) chosen studies, (b) choices of students in doubt, and (c) the influences on study choice (see Appendix D. Word web Study 1). These subjects match the determinants seen in Table 4 and in the framework of Kemper et al. (2007). These determinants: attitude, subjective norm and self-efficacy are paired with the recurring subjects that came out of the interviews in study 1. An important aspect of the research questions to be taken into account was whether noticeable issues relating to gender differences in study choice would arise. However, no striking statements were noted in the analysis of the transcriptions.

8.1.1. Chosen studies (attitude)

A number of Technasium students already knew what they were going to study after secondary school. This group was divided into graduating (sixth-grade) students and fifth-grade students. It was noteworthy that a number of students did not yet have a clear idea of their study choice. The studies chosen and discussed by the students were also of interest. Some students could say with certainty that they would not choose a STEM study, and students were looking for a course that did not specifically require secondary-school mathematics.

The STEM studies students mentioned could be divided into technological, medical and other STEM studies such as biology or chemistry. As can be seen in Table 7, most of the studies already chosen were STEM studies.

Table 7. Study courses mentioned in the interviews.

STEM	Boy	Girl	Medical	Boy	Girl	Other	Boy	Girl	Non-STEM	Boy	Girl
Industrial Design Engineering	2	2	Dentistry			Biology	1	1	Actor	1	
Architecture			Veterinary Medicine		1	Nanobiology		1	Econometrics		
Civil Engineering			Medicine	1					International Business Communication		1
Marine Technology			Biomedical Science		1	Chemistry			Teacher Training College		1
Clinical Technology						Geological Planning			Gap year	3	4
Sustainable Innovation											
Applied Physics											
Electrical Engineering	1										
Aerospace Engineering	2										
Mechanical Engineering	1	1									
Automotive Engineering											
Systems Engineering, Policy Analysis & Management											
Aviation Studies											
Natural Science and Innovation Management											

Note:The numbers alongside the studies indicate the numbers of students who had already made their study choice, divided into boys and girls.

A look at all the studies mentioned—including by students who were not yet sure of their choices—revealed STEM was popular among the possible choices. A number of students who were not sure what to choose were opting for a gap year. This group again was divided into students from the 6th and 5th grade. The others in the group did not have a clear idea of what to do after they finished secondary school.

8.1.2. Choices of students in doubt (attitude)

Students who were not sure what to choose often did have a list of studies that interested them. In this group one girl was looking for a course which did not have secondary-school physics as a prerequisite. The rest of the group were interested in studies in the STEM sector. However, students were unsure whether to choose a STEM or a medical study. Important factors behind their doubt, in harmony with the determinants regarding attitude, subjective norm and self-efficacy outlined by Kemper et al. (2007) were the importance of finding a good job, personal interests, family influences or the lack of mathematics at secondary school. Two girls who did not take mathematics at secondary school were considering completing a summer course to be able to choose a STEM or a medical study afterwards. One boy was torn between Aerospace Engineering, Marine Engineering and Medicine. His mother was a doctor, which meant he was familiar with the job, but his interest in airplanes and

design was making the choice between medical or STEM fields a hard one. Another boy had already applied for Medicine because of the selection procedure, but also because he wanted the guarantee of a good job in the future. However, he was still considering STEM study because of his interest in design and technological products.

Students who intended to have a gap year felt pressure to make the right study choice at once, or did not feel ready for university. One boy had to dedicate considerable time to finishing his secondary school in a satisfactory way, which caused him to postpone the matter of later study choices. He wanted to take time to orientate himself during a gap year before deciding how to continue his student career.

8.1.3. What influences the study choices of Technasium students?

The data gathered from the interviews showed that the choice of study was based on different factors. Students' interests, the school attended, and the O&O course were all elements for consideration.

Interests (attitude)

Many students mentioned that they thought their own interests were an important factor in deciding what to study after secondary school. Performing a job that they liked, and that suited their interests, was a goal for some.

> Student: *"I think it is important that if you have a job in the future, it is fun to do. Otherwise you will not keep doing that job."*
>
> Me: *"What influenced you the most in your study choice?"*
> Student: *"My interests, but also what I am good at."*

Some of these interests were developed during students' younger years through family, friends or sports and hobbies.

> *"Yes, I took up hockey because of my parents, and gaming because of my friends. I played games over at their houses and wanted to do it at home, too."*

One boy who was particularly interested in electronics had been inspired by a homemade present his father had given him during Saint Nicholas, a Dutch celebration where a present is hidden in a self-made package:

"My father made me a surprise for Saint Nicholas when I was young. He made something with small light bulbs on it, and I played with it afterwards and it got me interested. He also knows a lot about mathematics and that interests me too."

Sometimes, a student's own interests in a specific topic were the reason for study choice, even when the topic was not experienced positively at school:

"Strangely, [the subject of] biology did not at all influence my study choice. I think biology at secondary school is really different from university, so it was more my interest in biology in general that made me choose it."

Other influential factors at school (subjective norm)

Apart from the specific O&O course, there were other factors that could affect the decision-making process. Events such as university open days and study choice tests were often mentioned as a source of inspiration for a particular study choice. Various school courses provided ways for students to discover new study directions and uncover skills in different areas. This process already started after third grade, when students had to choose from four profiles that included two nature-oriented profiles (including STEM subjects) and two socially oriented profiles (including languages, art and history). Learners following the O&O course had to choose Nature & Technology (N&T) or Nature & Health (N&G) if they also wanted to continue with O&O. Those who selected this profile were taught subjects such as mathematics, physics, biology and chemistry.

Me: "Did you experience a 'Hey! Now I know what I want to do!' moment?"

Student: "Well, um, during lessons we were busy looking at a lot of different studies, and there were a few that sounded nice."

O&O (Self-efficacy)

A key factor in study choice in this group was the O&O course. During the conversation students repeatedly mentioned that the O&O course had influenced their choice of course or at least the general study direction.

One question asked during the group interviews was "Does O&O influence your study choice?" Twenty-five out of 42 students answered yes, confirming that O&O did influence their study choice or study direction.

The other 18 students did not feel this influence. Their interests, for example, were more important:

"No I don't think so. Maybe it's true that you stay interested in design and the STEM direction because of this course, because you are working with it all the time. But it wasn't O&O that made me know where to look."

It was of note that the influence of the O&O course in students' study choices recurred in their interview answers. This influence was experienced in four different ways:

Development of interests (attitude)

Students experienced O&O as a medium that provided a lot of opportunities for developing new interests in certain topics. Through contact with companies and employees they received information about professions and gained insight into the diversity of society and the STEM sector. New ideas as well as the experiences of clients and employees were shared with the students, and this inspired enthusiasm and new outlooks.

> Student: *"For me it does, I've done three projects about the ocean, so something to do with offshore. So it influenced me in that way, I guess."*
>
> Me: *"Do you think this course influenced you in your choice of study direction?"*
>
> Student: *"Oh, definitely! I once had a client who gave me a lot of new ideas and I rolled into this direction even more."*
>
> Me: *"Okay! So, he gave you more information, etc.?"*
>
> Student: *"Yes, when he found something new I thought, 'Interesting! I want to do that too!'"*

Self-reflection

A significant part of the O&O course involves self-reflection, with students often having to make reports of this kind. Self-reflection reports were a frequently mentioned subject, in positive, but also in negative ways.

> *"Yes, there's a lot of self-reflection, that's the stupid part of O&O. "*

However, most students understood why this self-reflection was important and how it could help in their future careers. Some students even stated that it helped them in choosing their field of study.

> *"Yes, for me O&O influenced not only my study choice, but also me as a person. So it played a big role in helping me see whether I'm a fighter, a strong solo worker or a team player…Pretty challenging, but also very important for improving yourself."*

Different STEM directions (self-efficacy)

While following the O&O course, students became familiar with different fields of STEM study. During the first three or four grades, regular assignments were given in a variety of STEM subjects from biology to architecture. During or after 10th (4VWO) grade, the students were allowed to choose their own assignments and companies. Because a broad view of STEM fields was obtained during their first

years, they could look for companies that matched their interests and the interests of their group. This acquaintance with a range of different companies, subjects and assignments helped the students to understand what their interests were. This realization occurred in two ways: discovering new interests, or discovering which study directions did not suit their interests.

> *"Yes, in the beginning I thought I would become a doctor, I want that, I want that! But while I was following O&O I noticed I really liked building stuff."*

> *"In my first years of O&O we had a project with a lot of biology, and I hated it! So, I really got to know I don't want to do anything connected with biology!"*

Looking for connections with O&O (self-efficacy)

In general, the research participants found O&O very enjoyable. Some students even looked for connections with this course in their study choice. Working in groups on different projects was seen as a pleasant way of working, and some students were hesitant about the idea of doing one job for the rest of their lives. Such reasoning helped establish how study choice was also measured in terms of the way it connected with the O&O course.

> *Me: "Are there people or other things that influenced you in your study choice?"*

> *Student: "Yes, O&O did. I was especially looking for study that connects with O&O, because I really liked it!"*

8.2. Study 2

As in Study 1, clusters of codes were formed initially from the transcriptions, in a word web showing notable categories (see Appendix E. Word web Study 2). Recurring subjects that students mentioned in the interviews when asked about the connection between their secondary-school experience and their first-year IDE experience were: choice of IDE, expectations of IDE, reality of IDE, preparation at secondary school, self-efficacy in IDE and important skills required in IDE.

8.2.1. Choice of IDE

Regular students (i.e., students that did not follow the Technasium program) mostly chose IDE because of the combination of technological and creative subjects. A technological profile at secondary school is a requisite for IDE, and most students liked the creative aspect added to the technological nature of this course. Students often mentioned mathematics and physics as subjects they enjoyed and were good at in secondary school. One regular student cited the combination of technological and creative aspects in combination with psychological and philosophical elements as a guiding factor in the choice of IDE.

> *"I was orienting towards different studies, because I liked subjects like mathematics and physics. But I did not like the idea of just studying one in particular. That's why I like this course, with its combination of these courses but also creativity, psychology and philosophy."*

Former Technasium students were in general influenced by Technasium in their choice of IDE. Ex-Technasium students sought a connection with the Technasium program because they had greatly enjoyed O&O. The O&O course was seen as precursor to IDE, so the choice of either IDE or architecture was an obvious one for ex-Technasium students.

> *"Um, well I noticed in 10th grade that we had a lot of technological projects. I really liked the designing part and being creative. For me it was a question of choosing between IDE or Architecture. Those were the most obvious choices."*

> *"I really saw O&O as a kind of mini IDE."*

Like the regular students, Ex-Technasium students enjoyed mathematics, physics and the combination of technological and creative subjects. One ex-Technasium student in particular was already busy working in a robot team, designing robots for competitions, before he applied for IDE. Learning about working in teams and getting used to design projects connected well with IDE.

> *"… I attended a robot team. There you find a lot of organization, how to manage a team, how to build a robot with that same team. I think this really matches IDE."*

One non-Technasium student mentioned a course in Public Understanding of Science (ANW, taught in the upper grades of some Dutch secondary schools) as an influence in choosing IDE. By allowing the student to follow the entire design cycle, the course was instrumental in the later decision to attend the IDE course.

> *"Yes, then you go through the design cycle, that's a lot of fun!"*

Interests and future plans to become automotive designers, or work for Apple or Google also motivated students to choose IDE.

> *"…also because I'm a big fan of Apple. I still dream of working at Apple in the future. IDE is the course that can get me there."*

> *"…and I was just thinking of working for companies like Google and Apple in the future."*

8.2.2. Expectations

The group of regular students had a general expectation about what was going to happen in their first year. The ''romantic way of designing'', by which students meant the practical part of design involving visualizing and shaping, was mentioned by a few of the interview subjects when asked about their expectations of IDE. Students expected to learn how to come up with a good idea and develop it right to the finished product.

> "*Well, that you come up with a good idea, and you totally focus on that idea and take it through to a good final product."*

> *"Maybe this is because you always see that romantic story from designers: out of the blue a good idea comes up because there was this problem, and then this came out..."*

However, some expected to learn how to generate these ideas and were even a little bit afraid that they could not come up with good ideas.

> *"I expected to learn how to generate ideas. It was my biggest fear not to be able to come up with good ideas, but you learn how to do that."*

Expectations from the ex-Technasium group were a little more clearly specified than the regular students group. They also expected to make a lot of products, but in addition they expected to learn more about the design process and thought it would connect with O&O in a more technological way.

> *"I thought IDE would be something like Technasium, but with more rules and more methods."*

Marketing was also foreseen as part of the course. Students expected to learn about what role the consumer plays in the design of a product. The ex-Technasium group also talked about the freedom

they hoped to be given in their first year of IDE. In the last two years of the Technasium program the students had been allowed considerable freedom in choosing subjects and planning, and they hoped to enjoy similar freedom during IDE.

When asked whether their image of IDE study had changed after their first year, more students in the non-Technasium group answered affirmatively, at levels of between 28-80% compared to the 30-60% levels of ex-Technasium students (see Table 8). Because of the small sample groups, these numbers do not provide quantitative information. They do give insight into possible differences between the groups.

Table 8. Student views on design changed (or not) after first year of IDE

Views on design changed			
Ex-Technasium students		**Regular students**	
Respondent	Score	Respondent	Score
1.	40%	9.	28%
2.	30%	10.	40%
3.	30%	11.	50%
4.	40%	12.	70%
5.	35%	13.	75%
6.	60%	14.	60%
7.	50%	15.	75%
8.	35%	16.	80%
	Average: 40%		**Average: 59.75%**

Note. 1% = not changed at all; 100% = changed radically

8.2.3. Reality of IDE

Neither group described first-year IDE as being very difficult. However, because the projects were time-consuming, planning was often mentioned as an important skill to develop. Long workdays were frequent. Students noticed they were taught many design methods, which made them realize design was more complex than they had initially expected. Learning these new design methods went well, and they did not experience any gaps in knowledge. In fact, many new skills were taught in the first year.

> *"…I think that a lot of transversal subjects you would not think of normally are handed to you in this study. It makes your view broader."*

In contrast with the positive aspects of the design methods, students from both the ex-Technasium group and the regular student group thought these methods limited their creativity in designing a product, and they had doubts about their usability in real-life design projects.

Student: "But there was a lot more designing than I expected, for example the design methods. I never would have thought that, but it is a big part of this study. For me that was the biggest surprise."

Me: "In a positive way?"

Student: "Not totally, it limits you as a student. The projects you do here are mostly something like 'Design a playset with several requirements'. And then you're already…"

Me: "Limited?"

Student: "Yes, exactly! But the steps you have to take are not [suggested] in a negative way, it can help you in the process."

Some ex Technasium students experienced a regression in their first-level courses. The Practical Design course 1 (PO1) was seen as going back to basics for the more experienced ex-Technasium students. Moreover, the lack of freedom disappointed a few students, as the mandatory usage of design methods in projects felt like going back to secondary school.

"It was like a step back from Technasium to here. It felt like I was going back to 10th or 9th grade—better, of course, but it gave me that feeling. Coming from a lot of freedom where you could do what you wanted, and make very nice projects with the companies. Going to this, the school way, strict and just practicing."

Ex-Technasium students mentioned skill transfer in the transition from O&O at secondary school to the IDE Research & Design (R&D) program, as well as in terms of group projects. Both courses require research and design, and continuity is therefore optimal. Group projects are also common at IDE. Experience in group work is seen as an advantage in this first year by ex-Technasium students.

Student: "I did group work for 7 years, so I have a lot of experience with that."

Me: "Do you see that as an advantage?"

Student: "Yes I see it as quite a big advantage. You are able to manage people in a group, not as a leader, but more like a team member."

Both groups agreed that mathematics and physics at secondary school made the transition to IDE smooth. The STEM courses at IDE connected well to the STEM courses at secondary school, and neither group of students experienced any shortcomings in knowledge.

Both groups mentioned that a negative part of first-year IDE was the way projects were graded. Some courses were relatively interpretative, and the grade could depend on which supervisor you had during that course.

> *"It really depends on who you have as supervisor. There has been trouble with that. One time you are lucky and the other time you are unlucky with your supervisor. If you compare your work, your logbook, for example, you see yours is better. And still you have a lower grade."*

8.2.4. Preparation

Answers to the question of how well secondary school prepared the students depended on a number of factors. The course package at secondary school with mathematics and physics prepared the students for the STEM courses at IDE. The general experience was that the curricula of the STEM courses connected well with IDE STEM courses and gave students the preparation they needed.

However, most of the regular students did not have a creative course in their secondary-school profile and a number said the creative process was something that took getting used to at the beginning of first-year IDE. Learning these creative design processes was not, however, experienced as difficult, and students did not experience a lack of knowledge beforehand.

> *"I was perfectly prepared on the STEM courses, and I don't see any problems with that."*

> *"…maybe they could help you a bit more with the creative process. At secondary school you don't get to learn that at all. How to be open to all your [own] brainstorms."*

Ex Technasium students agreed that the degree of preparation for IDE depended on what kind of projects were carried out. Because of the freedom in the Technasium program, some students chose research rather than design projects in their last years. The students who did choose design projects said they felt better prepared in terms of completing a design cycle and becoming familiar with a creative process. One answer to the question of how well the Technasium program connected with first-year IDE was:

> *"I think it really depends on which Technasium course you were on. I have spoken to a lot of people from different Technasium schools, and you hear different stories. I think looking at how our Technasium was, working with real companies, keeping logbooks and planning, I go for a 75-80% connection."*

Some former Technasium students experienced advantages in planning, presenting and team work in their first year. Presenting especially was listed as a well-developed skill in comparison with regular students.

Me: *"Have you noticed a lead compared to regular students who did not follow the Technasium program? Or do you think there is not much of a difference?*

Student: *"Yes, a little lead at the start of this first year. You just know how the design cycle works, and how much time it takes to work it through. Also, more experience in presenting."*

However, this preparation was not seen to be very important for getting through the first year of IDE. Students stated that these preparations were handy at the very beginning, but that the skills of presenting and design methods were also taught very well within IDE.

"You just need physics and mathematics. Technasium is not required but it is really handy."

"You have some experience in project work, planning, keeping your logbook and knowing why you have to do that."

8.2.5. How difficult or easy is IDE?

Students had clear ideas about the question "How difficult or easy is IDE?". As shown in Table 9, on a scale of 1-100%, where 1% represents the maximum difficulty and 100% the easiest-level task, the regular student group rated IDE between 75-90%, while the ex-Technasium students group rated it between 50-90%. Once again, the small sample size could not supply any quantitative information. The numbers provide an overview of what could possibly be different between the two groups of students.

Table 9. How difficult or easy is IDE?

How difficult or easy is IDE?			
Ex Technasium students		Regular students	
Respondent	Score	Respondent	Score
1.	80%	9.	80%
2.	70%	10.	75%
3.	90%	11.	70%
4.	50%	12.	75%
5.	70%	13.	80%
6.	70%	14.	75%
7.	75%	15.	75%
8.	90%	16.	90%
	Average: 74%		Average: 78%

Note. 1% = most difficult; 100% = least difficult

Planning was a skill that students wanted to dedicate attention to in future projects. Moreover, the difficulty experienced within IDE depended on the subjects of the separate courses. Generally speaking, however, after one year students did not expect problems in following IDE.

One ex-Technasium student mentioned problems following the Practical Design course 2 (PO2) at IDE. PO2 was regarded as a key course, and because he had not passed it, consultation with the study advisor had been scheduled.

One student mentioned the IDE honors program. To be allowed to take part in this program, students needed an average grade of 7.5 in their first year. The reason this particular student wanted to apply for the honors program was to work in teams on extra projects. The connection with O&O is made by this participant. The O&O course was seen to offer greater opportunities for teamwork, more diverse knowledge and a more professional approach.

"At Technasium you were designing in groups, that is the experience I had and I miss that at IDE. I hope to find that in the honors program. I want to apply for that next year."

8.2.6. Important skills at IDE

The two groups of students were asked to list the most important skills they learned and needed on the IDE course. Both cited handling software, drawing, broad thinking, presentation skills, teamwork and planning as important skills in this field of study. These skills were called by both of the groups. Next to these skills, the students who did not follow O&O also mentioned dealing with stress, material knowledge, marketing, interaction, researching and knowing the relevance of the course. The ex-Technasium students mentioned discipline, calculus, creativity, self-reflection, building and documenting as important skills.

9. Conclusion

This study was conducted to answer two research questions: How do first-year students who completed the O&O course experience the transition to a STEM degree course (IDE at TU Delft), in comparison with students who did not follow the O&O course? And how does the Technasium O&O course at secondary school influence the choice of a (STEM) study program at university? The results from the two sets of interviews conducted as research shape the answer to these questions. In this research, a framework (Kemper et al. 2007), deducted from Ajzen's theory of planned behavior (1991), is used to see whether the determinants mentioned in the framework recurred in the context of Technasium students. Using the two research questions, I aimed to get insight in how the influences from O&O on study choice could possibly be an advantage in the transition to IDE.

9.1. Influences of O&O

Technasium students mainly choose to pursue STEM or medical studies, with the majority leaning towards the STEM side. Factors influencing the final decision include personal interests, the secondary school which students attended and the O&O course. Interests are cultivated according to environmental influences such as family, friends, sports and school. Events such as open days at universities were also cited as important factors in forming preferences, and this finding confirms the impact of the subjective norm—as highlighted by Kemper et al. (2007)—on study choice. Influencing factors such as parents, friends and school literally match the subjective norm outlined in Ajzen's theory of planned behavior (1991).

A group of students saw the O&O course as an important factor in study choice. The way Technasium students talked about becoming familiar with different STEM directions and developing new interests during the course suggests that O&O does influence subsequent study choice. Students gain knowledge of work environment by participating in projects with external clients. In addition, learning what not to choose, and gaining insight into their own identity through self-reflection were mentioned as advantages that placed this course above others in terms of shaping an idea of study choice. First-year IDE students who followed the Technasium program at secondary school also cited O&O as a strong influence on their choice of IDE, with O&O acting as a precursor to IDE. A direct line can be drawn between the self-efficacy factors in Table 1 in the Theoretical framework chapter of this thesis and Ajzen's theory of planned behavior (1991).

9.2. First-year experience of IDE

Differences in the first-year experiences of the students who did not follow the O&O course and those who did can be described in terms of the degree of preparation received at secondary school and the familiarity with the creative and design process. Both groups of first-year students felt satisfied with the level of preparation provided during the mathematics and physics courses they had taken at secondary school. These subjects were necessary to apply for IDE, and students agreed that they were essential requisites for the course.

Views on design changed most for the student group that did not follow the O&O course. This finding indicates that ex-Technasium students may have a better understanding of what to expect before entering first-year IDE.

The lack of creative subjects in their secondary-school curricula was initially a disadvantage for regular students attending the IDE course, whereas ex-Technasium students were more familiar with creative and design processes. However, ex-Technasium students agreed that the degree of familiarity varied depending on which Technasium school they had attended, and whether they had focused more on research or design projects. Presenting, planning and working in teams were core qualities ex-Technasium students developed more extensively compared to regular students. Some of the ex-Technasium students even experienced the first courses at IDE as a return to the basics. Moreover, the transition from enjoying more freedom during projects in the Technasium program to the stricter, more rigidly prescribed projects at IDE was seen as a drawback. Regular students did not experience any lack of preparation, except in terms of familiarity with the creative process.

9.3. General summary

Overall, the Technasium program at secondary school influenced students' study choices mainly by guiding them towards STEM and medical studies. This outcome is in line with the framework made by Kemper et al. (2007) based on the theory of planned behavior by Ajzen, (1991), and in the research at hand such aspects as attitude, subjective norm and self-efficacy—all described in Ajzen's theory—are similarly viewed as important factors affecting study choices. Interesting is to see how the theory of planned behavior works in the context of the Technasium program. Subjective norm emerged as family, friends, the school these students attended but also open days to universities were called as influential factors for their behavior. The influence of the O&O course in increasing knowledge about different STEM studies, is an explanation of the self-efficacy determinant in this context. These insights confirm the thoughts of the Technasium foundation pronounced in the Technasium guide (Bruning, H. 2014), and are very useful in informing potential Technasium students and their parents.

After passing the O&O course, ex-Technasium students experienced a certain advantage during the first year of IDE at TU Delft. This advantage can mainly be attributed to extra experience in teamwork and giving presentations, compared to students who did not attend the O&O course. Students who have completed the Technasium program are considered to be more familiar with creative and design processes, whereas some regular students initially had difficulties adjusting their way of thinking in this sense. On the other hand of this transition, ex-Technasium students could feel like taking a step back working for fictitious clients at IDE instead of real clients at Technasium. Because there is such a low number of ex-Technasium students, this is not a major concert for TU Delft.

10. Discussion and recommendations

This study uses a qualitative approach to gain a better understanding of the connection between the Technasium program and first-year IDE at TU Delft. First, it examines the study choices of graduating students at Technasium secondary schools. How did the O&O course influence the Technasium students in their choice of study? What were the other important influences on that choice? In this research, influential factors from O&O in study choice are compared with a framework from Kemper et al. (2007). In this framework attitude, subjective norm and self-efficacy act as clusters of variables. Ajzen's theory of planned behavior is used to construct this framework. The variables in the framework are used to expound the study choice students make. The results in this research show how these variables are expressed in the context of Technasium students making their study choice. The theory of planned behavior is a general theory to describe how our intentions and behavior is formed based on these three factors: attitude, subjective norm and self-efficacy. The study choice behavior of the group of Technasium students seems to fit into this theory of planned behavior. This comparison, however, does not give us the required amount of data needed to generate information about how students will perform their study choice.

Because two out of the four graduating classes at the participating secondary schools could not be reached, they were replaced by fifth-grade classes. In terms of the results of this study, the limited representation of Technasium graduating groups may be viewed as a limitation. However, both fifth and sixth grades showed nearly the same number of students who were either in doubt or completely undecided as to their tertiary study choices. According to Cabrera and La Nasa (2000), fifth and sixth-grade students show the same levels of educational decision-making, a consideration which supports the inclusion of both groups in this study.

In the data collection process, I have not deviated from the interview protocols. The data is stored as transcripts, and can be made available for further analysis upon request. The probing questions that

were applied in the interviews can be found in the transcripts as well. A potential improvement of this research, is that the probing questions could have been identified in advance of the interviews. By pre-identification of probing questions, the interview protocols would be clearer and thereby further improving the reliability of this research.

In this research, understanding of some aspect of thoughts and experiences have come apparent. To be able to generalize these thoughts and experiences, quantitative research is necessary. External validity is not reached in this research, however, the qualitative data acts as the basis for further quantitative research. An example of further analysis, is to understand whether ex-Technasium students score better in first year IDE at TU Delft. Or to broaden this scope, whether there are differences in grades at the end of the IDE course.

10.1. Study choice

Because of the limited number of students who had already chosen a specific field of study, it was difficult to conclude whether there was a difference in study choices between boys and girls. This also meant few conclusions could be drawn regarding whether students had chosen STEM as opposed to medical studies. One recommendation for further research is therefore to enlarge the sample size and conduct a longitudinal study to gain more understanding about the study choices of Technasium students. Will this chance from year to year, or will there be a fixed pattern to be discovered? Furthermore, by adopting an identical study for the HAVO Technasium program at secondary school, a comparison could be made.

It was not possible to obtain clear information about a difference in the reason for study choice between boys and girls, such as that described by Van der Veen and Blume (2015). Data from this study shows that most of the students opting for STEM courses are boys. This outcome is in line with the theory that boys are more interested in STEM studies than medical studies (Beede & Julian, 2011; Siann & Callaghan, 2001; Sjøberg & Schreiner, 2010), although the data on this occasion was drawn from a relatively small sample group. The study by Van der Veen & Blume (2015) showed that at Technasium secondary schools, less girls were choosing STEM studies in comparison with boys. By contrast, in this study the same number of boys as girls in Technasium secondary schools opted for a STEM study. However, students in doubt were not taken into account, and results could possibly change once their study choices became known. This research does not dive into the gender differences enough to conclude anything about these differences in the context of STEM. There are many different ways of research needed to form an idea of why women are underrepresented in STEM, because of the wide range of factors that could possibly influence this underrepresentation. Longitudinal research on Technasium secondary schools could reveal more about boys' and girls'

study choices and enhance understanding of the differences between them in the context of Technasium.

10.2. Influences on study choice

The factors students mentioned regarding the influences on their study choices can be fitted into the framework of Kemper et al. (2007). Students' attitudes towards a particular area of study were reflected in the aspects of continuity with the O&O course that were seen as desirable, the interests in a certain profession and the perceived connection between O&O and IDE in terms of difficulty. Environmental influences (subjective norm) from parents, friends and school were also recurring elements in the conversations. Students' interests were fostered through their home situation, open-day university events, school courses, group work and their own choice of projects. This was in line with existing theory about the impact of environmental factors on the development of interests (Aschbacher et al., 2010), the knowledge gained from group work (Watkins & Mazur, 2013) and the development of interests by choosing own projects (Prins et al., 2011).

Furthermore, Technasium students saw self-reflection as a tool that helped them in their study choices. Berzonsky and Kuk (2000) suggested that personal-identity development could help students in their transition from secondary school to university. However, self-reflection was not mentioned as an advantage for ex-Technasium students in first-year IDE at TU Delft. The O&O course influenced students in their study choice by revealing new career possibilities or study directions. On the other hand, O&O also produced negative experiences which could be useful in their own way, for example when doubt led a student to assess new ideas, or when a negative experience provided guidelines on what not to choose. These outcomes are in line with findings by Lichtenstein et al. (2007), which show that students can base their study choice on single positive or negative events. Moreover, Kemper et al. (2007) proposed that self-efficacy is an important variable in study choice. A recurring pattern in the interview conversations was that students mentioned O&O as an influential factor in their study choice and were even searching for some kind of continuity in a subsequent educational experience. These students could be said to feel empowered in relation to the course. Reasons for this empowerment were in line with the conclusions by Prins et al. (2011) in their research about the Technasium program. Choosing projects that suited their own interests motivated the students to fulfill the tasks and develop new interests. In the case of the O&O course, self-efficacy was raised because of these positive experiences. The present study suggests that O&O influences students in their choice of a STEM study option. However, the question remains as to whether students who chose O&O would still have applied for STEM study if they had not followed the Technasium program. This raises the question, whether O&O is potentially cannibalizing the contribution of STEM in education. Future research, could elaborate on the actual positive effect of O&O on the technical knowledge of the students. Suggested research, could compare the technical knowledge of two

separate groups of students. The first group consists of students from schools that have no Technasium program, and have technical exposure limited to the STEM courses. The second group consists of students enrolled in the Technasium program. Comparing the technical knowledge and skills of these two groups, could potentially give insight in the value of Technasium in secondary education.

Looking at regular VWO education, students attend open days at universities, and participate in study choice tests. As part of the curriculum, the students are required to choose a study direction at the end of third grade, which is not really different compared to the Technasium students. Compared to the Technasium program, the VWO program contains relatively less self-reflection. However, research could be done to further understand the possible differences between regular VWO and Technasium, in terms of determinants of study choice.

This research shows how the determining factors from the theory of planned behavior from Ajzen., (1991), relate to the context of Technasium students during their study choice. However, these insights do not provide tools to predict how people behave, but show us how their behavior develops and which factors influence this behavior. Determinants in study choice, revealed in the framework from Kempert et al., (2007), were appointed by the Technasium students as influential factors in their study choice. The question remains, whether these factors really change the attitude towards a specific field of study, whereas students already have to choose for Technasium in their transition from primary school to secondary school. When students decide to enroll in the Technasium program, they tend to have a distinctive interest in STEM already. All in all, the theory of planned behavior is one way of observing human behavior, but it can be argued that other theories are determinant as well. Future research is therefore suggested to explore this in further extend.

10.3. First-year IDE

This study shows that ex-Technasium students experienced advantages in their first year of IDE compared to regular students, as a result of their preparation at a Technasium secondary school. However, little is yet known about the study results. How do these ex-Technasium students develop during and after their IDE Bachelor's and Master's studies compared to regular students who did not follow the Technasium program at secondary school? Quantitative research about study results and drop-out rates of ex-Technasium students could highlight the possible consequences that following a Technasium program at secondary school has on studying IDE and on future careers, compared to regular students.

10.4. Difference between boys and girls

As regards the differences between the study choices of boys and girls at Technasium secondary schools, the results are scattered. Earlier studies show that women are more interested in healthcare and physical sciences than men, who are usually more interested in engineering (Beede & Julian, 2011). There is a lack of female role models in the STEM sector (Sjøberg & Schreiner, 2010). In the discussions for this study, however, no differences between boys and girls could be surfaced. This could be due to limitations in the number of students that applied for STEM or medical study. Also, the interview protocol did not dive deep enough into this part of the research. However, interest in specific STEM studies was more common in boys than in girls. This is only an observation in this specific sample group, and the question remains whether results will be the same in a larger group. Therefore, no conclusions can be drawn out of this research about gender differences and the way that effects their study choice.

10.5. Choosing for a gap year

The main research question explored the transition between the Technasium program and IDE at TU Delft; however, during the discussions a considerable number of students expressed the decision to take a gap year after graduating. Since September 2015, scholarships from the Dutch government have been abolished (Maatregelen - DUO., n.d.). Moreover, students are no longer able to switch studies without financial consequence. With the abolishment of the scholarship, students possibly feel more pressure to choose the right degree course at once, to reduce costs. The year before the abolishment saw the largest student intake from high school to college or university in 10 years (Meer vwo'ers direct naar de universiteit, 2016). This statistic reinforces the theory that the end of the scholarship program may also have impacted on current study choices in the Netherlands.

This research indicates that the Technasium program functions to some extent as a nursery for students choosing STEM or medical study. Further research is required to show whether the Technasium program is the determining factor that motivates more students to choose STEM studies. Establishing this link with more certainty also depends on monitoring the eventual choices of students who were still in doubt at the time of this research.

TU Delft has already implemented an honors program for students with higher-than-average performance, to challenge them in their studies (Honours Program Bachelor, 2016). This program is designed for students to delve deeper into their various courses, and it allows them to construct a program according to their own interests. From the second year onwards students can take this path, going on to complete it in the third year of the IDE bachelor's program. For ex-Technasium students who experienced the first year as something of a regression, the Honours Program could represent a stimulating added challenge.

11. References

Ajzen, I. (1991). The theory of planned behaviour. Organizational behaviour and human decision processes, 50, 179-211.

Argyropoulou, D. (n.d). Applications of Self- Efficacy Theory to the Understanding Career Decision Making of Higher Education Students. University of Athens, Greece: Department of Psychology.

Aschbacher, E. (2009). Is Science Me? High School Students' Identities, Participation and Aspirations in Science, Engineering, and Medicine. California: California Institute of Technology.

Briggs, A., Clark, J. & Hall, I. (2012) Building bridges: understanding student transition to university, Quality in Higher Education, 18:1, 3-21, DOI: 10.1080/13538322.2011.614468

Beede, N., Julian, Tiffany, A., Langdon, David, McKittrick, George, Khan, Beethika, Doms & Mark E., (August 1, 2011). Women in STEM: A Gender Gap to Innovation. Economics and Statistics Administration Issue Brief No. 04-11. Retrieved at SSRN: http://ssrn.com/abstract=1964782

Berzonsky, M. & Kuk, L (2000) Identity status, identity processing style, and the

transition to university. Journal of Adolescent Research 15, 81 - 99.

Block, P. (1987). The empowered manager: Positive political skills at work. San Francisco, Jossey-Bass.

Briggs, A., Clark, J. & Hall, I. (2009), 'Bridging the Gap: project report on student transition', Newcastle University, UK

Bruning, H. (2014). Handreiking schoolexamen Onderzoek & ontwerpen havo/vwo. Enschede, SLO (nationaal expertisecentrum leerplanontwikkeling).

Bryman, A. (2012). Qualitative data analysis. In A. Bryman, Social research methods (pp. 568-569). Oxford, Oxford University Press.

Cabrera, A. & La Nasa, S. (2000), Understanding the College-Choice Process. New Directions for Institutional Research, 2000: 5–22. doi: 10.1002/ir.10701

Creswell, J. (2006). Five Qualitative Approaches to Inquiry. In J. W. Creswell, Qualitative Inquiry and Research Design (pp. 64-66). Lincoln, USA: University of Nebraska.

Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 84, 287–312.

Honours Programme Bachelor. (n.d.). Retrieved March 07, 2016, from http://studenten.tudelft.nl/en/students/education/honours-programme-delft/honours-programme-bachelor/

Industrieel Ontwerpen. (2016). Retrieved February 18, 2016, from http://www.tudelft.nl/nl/studeren/bacheloropleidingen/overzicht-opleidingen/industrieel-ontwerpen/

Instroom nieuwe bachelorstudenten. (n.d.). Retrieved March 07, 2016, from http://www.vsnu.nl/f_c_instroom_bachelor.html

Kemper, van Hoof, Visser & de Jong. (2007) Studiekeuze in kaart gebracht: gedragsdeterminanten van scholieren bij het kiezen van een vervolgopleiding. Tijdschrift voor Hoger Onderwijs, 25 (4). pp. 270-279. ISSN 0168-1095

Lichtenstein, G., Loshbaugh, H., Claar, B., Bailey, T. & Sheppard, S. (2007). Should I stay or should go? Engineering students' persistence is based on little experience or data. Proceedings of the American Society for Engineering Education Annual Conference, Honolulu, Hawaii.

Luechauer, D. & Shulman, G. (1993). Empowerment at work: Separating folklore from fact. At work: Stories of tomorrow's workplace. 2(6), 13-14.

Maatregelen - DUO. (n.d.). Retrieved June 30, 2016, from https://duo.nl/particulier/studievoorschot/maatregelen.jsp

Meer vwo'ers direct naar de universiteit. (2016, January 12). Retrieved June 30, 2016, from Meer vwo'ers direct naar de universiteit, https://www.cbs.nl/nl-nl/nieuws/2016/02/meer-vwo-ers-direct-naar-de-universiteit

Nationaal Techniekpact 2020 (2013). Retrieved February 2016 from http://www.rijksoverheid.nl/documenten-en-publicaties/convenanten/2013/05/13/nationaal-techniekpact-2020.html.

Prins, G., Vos, M. & Pilot, A. (2011). Leerlingpercepties van Onderzoek & Ontwerpen in het technasium: Freudenthal Instituut voor Didactiek van Wiskunde en Natuurwetenschappen, Utrecht.

Schiefele, U. (1991). Interest, learning, and motivation. Educational psychologist, 26(3-4), 318

Scholen | Technasium.nl. (n.d.). Retrieved February 08, 2016, from https://www.technasium.nl/netwerken/netwerken/overzicht.

Siann & Callaghan (2001) Choices and Barriers: Factors influencing women's choice of higher education in science, engineering and technology, Journal of Further and Higher Education, 25:1, 85-95, DOI: 10.1080/03098770020030524

Sidiropoulou , D.-D. (1993). Development of decision-making skill in the context of School Career Guidance. NEA PAIDEIA, 66, 23-31.

Sjøberg, S. & Schreiner, C. (2010). The ROSE project: An overview and key findings. Oslo: University of Oslo.

Technasium Nederland. (2014). Technasium werkt door!. Geraadpleegd van https://meridiaan-college.mwp.nl/Portals/0/meridiaan2011/HL_BESTANDEN/Onderwijs/Leerlingen/Technasium/2014-2015/Folder%20doorstroom%20MN%202014.pdf

Van der Neut, R. (2013). Het effect van technasia op de motivatie en studiekeuze van leerlinge. Tilburg: IVA Onderwijs.

Veen, J. & van der Blume, A. (2015) Engineering in Dutch Schools: Impact on Study Choice – A quantative analysis.In: 43rd Annual SEFI Conference, 29-06-2015 - 02-07-2015, Orleans.

Vereniging van Universiteiten (VSNU). (2014). De Nederlandse Gedragscode Wetenschapsbeoefening Principes van goed wetenschappelijk onderwijs en onderzoek. Geraadpleegd van

http://www.vsnu.nl/files/documenten/Domeinen/Onderzoek/Code_wetenschapsbeoefening_2004_(2014).pdf

Wat is het technasium? | Technasium.nl. (n.d.). Retrieved June 27, 2016, from https://www.technasium.nl/wat-het-technasium

Watkins, J. & Mazur, E. (2013). Retaining students in science, technology, engineering and mathematics(STEM) majors.Journal of College Science Teaching, 42(5), 36–41.

12. Appendix A learning objectives IDE

Mens en product

1.De student heeft algemene kennis van consumentengedrag.
2. De student heeft kennis van de belangrijkste aspecten die het gedrag van de consument beïnvloeden.
3. De student heeft kennis van de belangrijkste begrippen en principes uit de fysieke, sensorische en cognitieve ergonomie.
4. De student heeft inzicht en vaardigheid in het opzetten van eenvoudig ergonomisch onderzoek.
5. De student heeft een globaal overzicht van bestaande informatiebronnen en hun reikwijdte op het gebied van consumentenonderzoek en ergonomie; de student heeft enige vaardigheid in het zoeken naar informatie binnen die bronnen.
6. De student kan gedrag van gebruikers en consumenten herkennen en de verkregen inzichten koppelen aan ontwerpproblemen

PO1

1. De student heeft elementaire kennis van Industrieel Ontwerpen als vakgebied.
2. De student is bekend met de faciliteiten en organisatie van de faculteit en de inrichting en reglementering van het onderwijs.
3. De student is bekend met de (veiligheid)voorschriften voor het gebruik van eenvoudige gereedschappen en de afspraken voor werken in de modelwerkplaats.
4. De student kent ontwerp methodologische basisbegrippen en de fasen van het ontwerpproces.
5. De student weet wat de belangrijkste aspecten zijn die bij productontwerpen een rol spelen.
6. De student kan een eenvoudig ontwerp probleem herkennen, informatie verzamelen en verbanden leggen.
7. De student kan een eenvoudig ontwerp maken en genomen ontwerpbeslissingen beargumenteren.
8. De student kan eenvoudige fysieke modellen vervaardigen.
9. De student kan met eenvoudige middelen ontwerpideeën visualiseren en technisch documenteren.
10. De student kan reflecteren op eigen ontwerpactiviteiten en heeft inzicht in de eigen geschiktheid voor de opleiding IO en voor de toekomstige beroepspraktijk.

Design X

Study goals / competencies

Aesthetics:

- The student is capable to see the formal characteristics of a given shape as a kind of language that can be (re)used and manipulated to serve different goals:
- The student is capable to manipulate form language in relation to purely aesthetic references.
- The student is capable to manipulate form language in relation to cultural, emotive and functional references.
- The student is capable to capture the essence of a shape in a consequent and pure form language.

Form integration:

The student is capable to integrate shapes with different qualities in terms of form language.

Color:

- The student is capable of analyzing color on its dimensional qualities, and can make balanced color suggestions for products on the basis of valid color combinations.

Product meaning

- The student recognizes the role a product plays for its owner, not only as carrier of personal or more general meaning, but also as means of personal expression, and is capable to substantiate this product role in both senses.

Rituals

- The student is capable of analyzing the interaction ritual a user has with a certain product and can make design decisions based on this analysis in order to improve the relationship between user and product.

Ad Hoc

- The student is capable of designing a product using the 'ad-hoc method'.

Product in werking

1. De student kan de rol van techniek bij het ontwerpen van producten verklaren.
2. De student kan technische (deel)functies in bestaande producten herkennen.
3. De student kan gangbare werktuigbouwkundige en elektr(on)ische deelsystemen in massaproducten en de (deel)functies die deze kunnen vervullen herkennen en verklaren.
4. De student kan op basis van een informele omschrijving van de gewenste werking van een te ontwerpen product technische (deel)functies voor dat product specificeren.
5. De student kan voor technische (deel)functies toepasbare werktuigbouwkundige en elektr(on)ische deelsystemen selecteren, samenvoegen en uitwerken op conceptueel niveau. Het betreft hier zowel deeloplossingen voor nieuw te ontwerpen producten als alternatieve oplossingen voor te herontwerpen producten.
6. De student kan met behulp van basiskennis van wiskunde, mechanica, en systeemleer technische productfuncties (quasi-statisch) modelleren.
7. Binnen het kader van de voornoemde basiskennis is de student in staat om met behulp van zelf opgestelde modellen de lijst van ontwerpparameters in een product op te stellen.
8. Op basis van zelf opgestelde modellen is de student in staat de werking van bestaande producten kwalitatief en kwantitatief te beschrijven.
9. Op basis van zelf opgestelde modellen is de student in staat de realiseerbaarheid van een conceptontwerp qua functievervulling te evalueren/beoordelen.
10. Voor realiseerbare concepten kan de student zelf opgestelde modellen toepassen om waarden voor ontwerpparameters te berekenen, hetzij handmatig, hetzij met behulp van eenvoudige computertools.
11. De student is zich bewust van de mogelijkheden en beperkingen van eenvoudige technische modellen.

Business Culture and Technology

Er wordt onderscheid gemaakt tussen vakspecifieke en generieke leerdoelen.

Vakspecifieke leerdoelen:

1. De student is zich bewust van de complexiteit van de omgeving waarin hij als Industrieel Ontwerper opereert.
2. De student heeft inzicht de business context in relatie tot productontwikkeling.
3. De student heeft inzicht de culturele context in relatie tot productontwikkeling.
4. De student heeft inzicht de technologische context in relatie tot productontwikkeling.
5. De student is in staat om de belangrijkste trends op bedrijfs-, cultureel en technologisch gebied te vertalen naar de praktijk van de productontwikkeling en van het industrieel ontwerpen op strategisch niveau.
6. De student is in staat om verantwoordelijke ontwerpbeslissingen te nemen die gebaseerd zijn op analyses van de bedrijfs-, culturele- en technologische contexten.

Generieke leerdoelen:

1. De student kent de methodieken om projecten doelmatig te plannen, te structureren en te beheersen.
2. De student kent de factoren die samenwerking in een team beïnvloeden.
3. De student heeft enig inzicht in de rol van presenteren en visualiseren voor het communiceren van (groep)resultaten.
4. De student kan op academisch niveau theorie uit verschillende bronnen zich eigen maken.

PO2

Bij PO2 Concept Design staan de volgende kernvraagstukken centraal:

1. Hoe komen ideeën en concepten voor nieuwe producten tot stand?
2. Hoe wordt de kwaliteit van productconcepten bepaald, gesimuleerd, getest en geëvalueerd?
3. Hoe worden ontwerpen en het ontwerpproces gedocumenteerd en gepresenteerd?

De vakspecifieke leerdoelen zijn:

1. De student kan een open ontwerpprobleem (her)formuleren en zijn/haar interpretatie rechtvaardigen.
2. De student kan, gegeven een open geformuleerd ontwerpprobleem, een conceptontwerp voor een nieuw product ontwikkelen.
3. De student kent de grote verscheidenheid aan aspecten die bij de productontwikkeling een rol speelt en kan deze aspecten integreren in een oorspronkelijk conceptontwerp.
4. De student kan op systematische wijze technische, ergonomische en esthetische kwaliteiten van het conceptontwerp (of deeloplossingen daarvan) m.b.v. modellen en simulaties voorspellen.
5. De student kan een conceptontwerp visualiseren en technische documenteren (het laatste m.b.v een 3D CAD programma).
6. De student kan een planning voor een ontwerpproject maken en uitvoeren.
7. De student heeft door kritisch reflecteren op eigen gedrag (denken, beslissen, handelen) inzicht in ontwerpmethoden en eigen werkwijzen en kan zijn/haar gedrag bijsturen.
8. De student kan het gevolgde ontwerpproces, de daarbij gehanteerde methoden, de ondernomen activiteiten, de verrichte onderzoeken en (concept) ontwerpen documenteren en presenteren.

Research and Design

1.The student knows the basic principles of empirical research.
2. The student will understand how research can help solving a design problem.
3. The student will have an overview of IDE relevant research methods.
4. The student will know how to formulate a research question, an hypothesis and how to conduct and analyze a small quantitative pilot experiment.
5. The student knows how to present and report research results.
6. The student will know how to set up a research proposal according to a scientific format and is able to communicate this proposal.
7. The student will learn to choose an appropriate method for data analysis and how to perform this analysis.
8. The student knows how to adequately use sources of information and is capable in selecting, understanding and applying relevant literature.

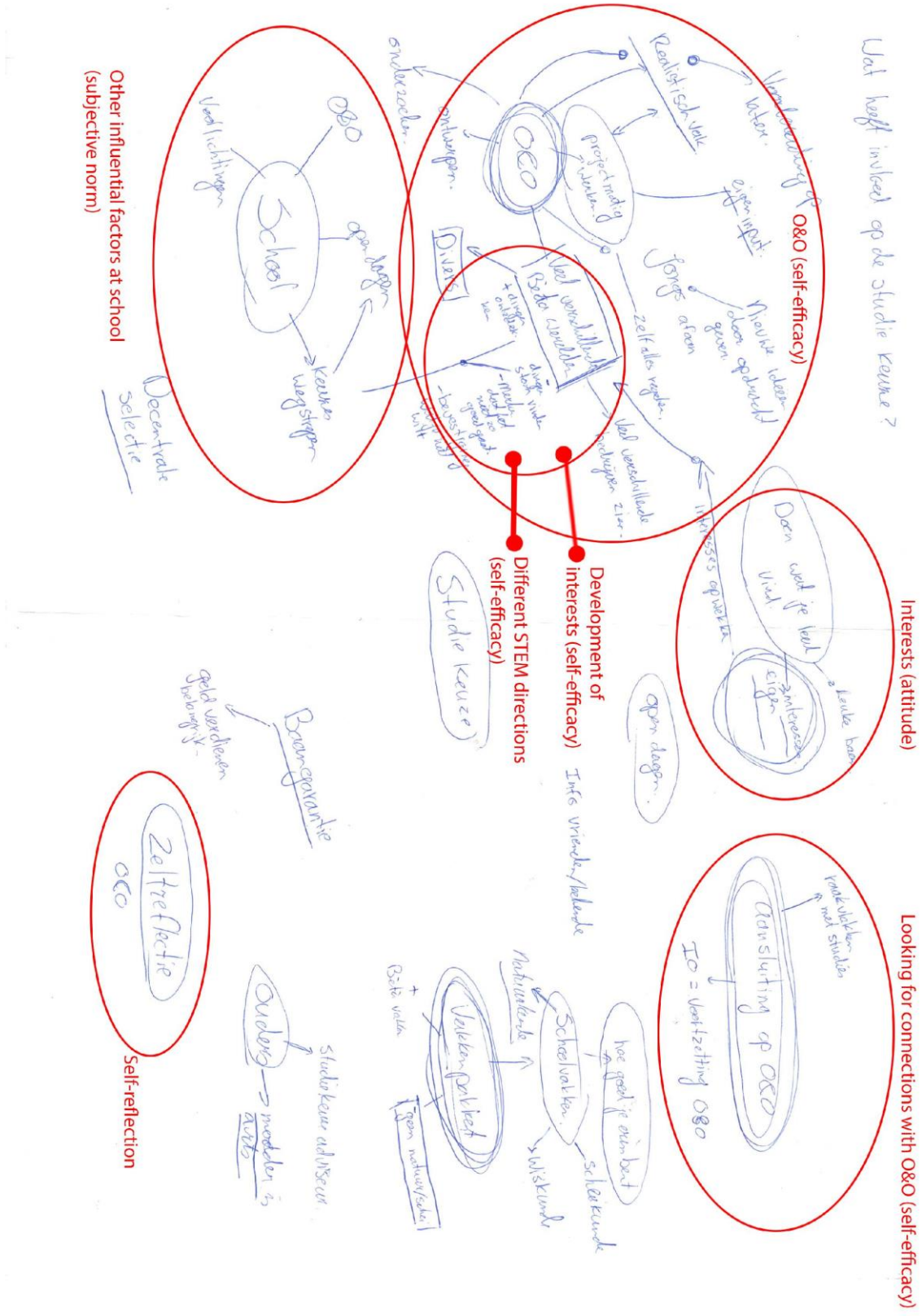
Appendix B. Interview protocol O&O students.

Asked questions
1. Huidige interesses (5-10 min) - **Wat zijn je huidige interesses, wat vind je leuk om te doen? Bijvoorbeeld hobby's, tijdsbesteding, sport.** - **Wat heeft volgens jouw invloed gehad op het ontwikkelen van deze interesses? (Vrienden, familie, school, media)** - **Met wie deel je deze interesses?**
2. Studiekeuze (10 min) - **Wat ga je doen na de middelbare school?** *(Wanneer een leerling hierin aangeeft dat hij/zij nog niet weet wat te doen hierover doorvragen waarom en wat voor acties er ondernomen gaan worden om erachter te komen)* - **Waarom wil je deze studie doen?** - Tussen welke studies heb je een keuze moeten maken? - **Wat heeft voor jou het meeste invloed gehad op je studiekeuze?** - Waarom heb je andere studies niet gekozen? - Wat voor baan zou je willen en waarom zou je dit graag willen? - *Vanaf wanneer wist je dat je deze studie wilde gaan doen, en hoe kwam dat?* - *Welke universiteiten/hoge scholen spreken je aan?* - *Wat zijn je verwachtingen van je vervolgestudie?* - *Ken je mensen die deze studie doen?*
3. Thuissituatie (5min) - **Wat voor werk of studie doen je gezinsleden? (Ouders/verzorgers, broers/zussen?)** *Vraag ook naar wat voor studie de ouders hebben gedaan.* - **Heeft dit invloed gehad op de ontwikkeling van jouw eigen interesses denk je?** *Zo ja, hoe?*
4. O&O (10 min) - **Waarom heb je voor O&O gekozen?** - Welke aspecten van O&O spreken je aan? - *Hoe ben je te weten gekomen over O&O?* - **Heeft het vak O&O een rol gespeeld in het kiezen van je studie?** - *Hebben andere vakken ook een rol gespeeld bij je studiekeuze denk je?* - **Ben je anders gaan denken over je toekomst door dit vak?**
5. IO (5min) - **Heb je weleens gehoord van ontwerpstudies?** - Wat denk je dat deze studies inhouden? - Wat denk je dat je met deze studies kan worden later? - **Heb je IO overwogen?** - **Zou IO/wtb/bouwkunde/ontwerpstudies aansluiten op het Technasium?**

Appendix C. Interview protocol first year students IDE

Questions asked
1. Hoe ervaren studenten de studie IO? - Wat waren de redenen dat je voor de studie IO hebt gekozen? *(Wat heeft een grote invloed gehad op je keuze?)* - Hebben schoolvakken hier nog een rol in gespeeld? - *(Heeft het vak O&O hier een rol in gespeeld?)* - Wat waren jouw verwachtingen van de studie IO, en jouw beeld van ontwerpen, voordat je hieraan begon? Denk aan de moeilijkheidsgraad, sfeer of onderwerpen. - Waar had je deze verwachtingen (dit beeld) op gebaseerd (bijv. school (O&O), familielid, open dag, media)? - In hoeverre zijn deze verwachtingen uitgekomen het afgelopen jaar? - Op een schaal van 1 tot 100%, hoeveel is jouw beeld van ontwerpen verandert het afgelopen jaar*? (Hier is 1%, je denkt nog steeds hetzelfde over ontwerpen als voordat je begon. En 100% is een totaal ander beeld van ontwerpen dan voordat je begon.) Leg uit waarom*
2. Vinden studenten dat ze een goede voorbereiding hebben gehad op de studie IO op de middelbare school? - Hoe heb je de overgang van VWO -> IO ervaren? Denk aan moeilijkheid, nieuwe onderwerpen, nieuwe manier van leren, meer tijd besteden? - Vind je dat de vakken die je op de middelbare school kreeg je goed hebben voorbereid op de studie IO? Zo ja, welke vakken waren dat? Hoe komt het dat juist deze vakken je goed hebben voorbereid (denk aan inhoud, gastsprekers, rol van de docent)? Zo nee, was er iets anders waardoor je je kon voorbereiden op de studie IO (denk aan familieleden, media, open dagen)? - Dit alles in overweging genomen, hoe goed voorbereid voelde je je toen je aan deze studie begon op een schaal van 1 tot 100%? *(hier is 1% je hebt totaal geen voorbereiding ervaren en 100% je wist precies wat en waarom je dit wilde en hoe dit ging worden)* Leg uit waarom
3. Hoe zelfverzekerd zijn studenten IO over hun capaciteiten binnen het ontwerp vak? (Wat is hun self-efficacy?) - Hoe heb je je eerste jaar IO ervaren? Denk aan uitdagingen, moeilijkheidsgraad, manier van werken. Wat was er positief, wat was er negatief? - Welke vaardigheden komen allemaal aan bod bij IO? - Welk van deze gaan je makkelijk af? Hoe denk je dat dit komt? ▪ Heeft dit iets te maken met je voorbereiding (/vooropleiding)? - Welk van deze gaan je minder makkelijk af? Hoe denk je dat dit komt? - Welke van deze vaardigheden bezat je misschien al op de middelbare school? (Denk aan werken in groepen, ontwerpmethoden, presenteren) - Wat vind je van het niveau dat gehanteerd wordt op IO? - Op een schaal van 1 tot 100%, hoe goed acht jij jezelf in staat om de studie IO te volgen? *(Hier is 1% onmogelijk om door te gaan en 100% het gaat je erg makkelijk af)* Leg uit waarom
4. (Only fort the ex Technasium students group) Als je denkt aan Technasium en IO, hoe goed denk jij dat dit op elkaar aansluit op een schaal van 1 tot 100%? Hierin is 1 procent: er is totaal geen goede aansluiting, en 100 procent: er is een perfecte aansluiting. Leg uit waarom. Wat zou er verbeterd kunnen worden aan deze aansluiting?

Appendix D. Word web study 1



Appendix E. Word web study 2