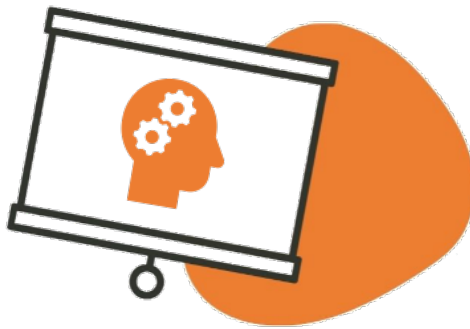# Creating adaptive master Applied Mathematics graduates:

Closing the gap between programme and professional career

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Summary

"Recent research on the outcomes of education, particularly at the tertiary level, has shown that there is a gap between the knowledge needed at work and the knowledge and skills produced through formal education." (Tynjälä, 2008)

The National Student Survey 2019, an annual student survey that investigates how satisfies students are with their study programme, showed that students of the master programme Applied Mathematics (AM) are not unanimously satisfied with the *preparation for their professional career*, which was also observed by the Lopuhaä in the Critical Reflection (Lopuhaä, 2019). Next to that, no entry was available for *Internship and Programme*, which also suggest students not being unanimously satisfied with offered preparation for the internship. Our goal was to develop an advice for the master programme Applied Mathematics to narrow the gap between programme and labour market, by finding out what enables (facilitators) or inhibits (barriers) students to be adaptive. The research question was: *How could the MSc Applied Mathematics programme at the TU Delft prepare the AM graduates for the start of their professional career by including adaptability in the curriculum?*

Adaptability or adaptivity is the competence which allows people to settle more easily in a new and unfamiliar environment. (Carbonell et al., 2014; Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000, 2006; Savickas, 1997) When alumni of the master programme enter a work environment after graduating, the environment is new and unfamiliar, and adaptability could help them start their career more smoothly. Literature was found about these adaptive competencies, and four adaptive competencies were discovered to be the most applicable for AM graduates: *Solving Problems Creatively, Learning new tasks, technologies and procedures, Demonstrating Interpersonal Adaptability, and Dealing with uncertain and unpredictable work situations.*

Several interviews with staff members of the master programme, the study association, Career & Counselling Services TU Delft, and also with a student and alumni were conducted to answer the question. The interviews with the master programme, study association and Career & Counselling Services obtained information on how the programme and other relevant departments prepare students for their professional career. The interviews with the alumni obtained information about adaptive situations they encountered related to the competencies, as well as the barriers and facilitators that inhibits or enables them to be adaptive. Next to that, a survey was used to find out if they were adaptive and to find which barriers and facilitators were the most relevant for AM graduates. With the results of the survey, two adaptive competencies, *Dealing with Uncertain and Unpredictable Work situations, and Demonstrating Interpersonal Adaptability,* were found to be most interested and relevant to include in the master programme*.*

A tool was developed for the internship to make students more aware about these competencies, make them practice these competencies at their internship by developing personal learning goals and have them reflect on their experiences at the end. This tool could make the AM students more adaptive, what might prepare them for their professional career.

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List of abbreviations

Abbreviation	Explanation
TU	University of Technology
AM	Applied Mathematics
Programme	Master Programme
NSE	National Student Enquête (Dutch)
	National Student Survey (English)
CH	Christiaan Huygens

1 Introduction

We live in a fast-changing world, where higher engineering education focusses on creating engineers that will deal with upcoming technological innovations. The future cannot be perfectly predicted, and therefore it is uncertain what we might face in the future. However, it is still important to think ahead and educate engineers that could work on these problems and develop technological solutions for them. But how do you know what the future needs and how do you create engineers that fit that view? Kamp (2016) proposes that "[the] skills of tomorrow's engineer must clearly go beyond the technical domain." (p. 19) Recruiters at organizations do not look at applicants' knowledge alone, but they also at "[more] elusive factors like ambition, creativity, patience, perseverance, international orientation, organizational sensitivity and social intelligence." (Kamp & Klaassen, 2016, p. 2) So as Kamp (2016) suggests, engineering programmes should not only focus on the technological depth, but they should "enrich and broaden the students' background as well." (p. 20)

An example of a technical-oriented engineering programme is the master programme Applied Mathematics at the University of Technology Delft, i.e., TU Delft. The study programme is a two-year master programme and is provided by the faculty Electrical Engineering, Mathematics and Computer Science (EEMCS). The Delft Institute of Mathematics (DIAM) is one of the six departments at the EEMCS faculty. "DIAM aims to model and analyse physical, technical and social phenomena using innovative mathematical techniques and methods." (Lopuhaä, 2019) The MSc programme Applied Mathematics educates students to create solutions for problems in science and engineering by applying methods, theories and tools of mathematics, with the deep applicable mathematical knowledge provided by the programme. (*MSc Applied Mathematics | TU Delft*, n.d.) The programmes objectives are (1) "to provide students with a thorough knowledge of pure and applied mathematics", and (2) "to develop expertise in applying the methods and tools of mathematics to problems in science and engineering." (Lopuhaä, 2019, p. 11) Mathematical modelling is central in the programme, and is studied from different angles, which separates them from other Mathematics programmes. However, they also offer in-depth mathematical knowledge, which separates them from Applied Mathematics programmes, where they focus on applying theory. The study programme consists of 120 worth of ECTS, has a non-mathematics elective part worth of 18 ECTS and a thesis project of 42 ECTS. The study programme obligates students to do an internship at a company, outside the TU Delft. Students have the possibility to choose between doing the internship as part of their non-mathematics elective part, or doing their master's thesis at a company.

Next to the programme, the TU Delft stimulates preparation for the professional career, by offering activities (Career & Counselling) or starting initiatives, such as the PREFER Project at Aerospace engineering[1].

1.1 Case: Master programme Applied Mathematics TU Delft

In 2019, a Critical Reflection of the master programme Applied Mathematics was developed (Lopuhaä, 2019), and the findings were gathered in a document. The Critical Reflection served

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[1] https://www.tudelft.nl/lr/actueel/stories-of-ae/het-prefer-project-wil-afgestudeerden-in-een-technische-richting-beter-voorbereiden-op-hun-loopbaan/

as a basis for the assessment of the programme, for which experts visited the faculty in May 2019. The document contains information about the programme in general, but also the objectives and exit qualifications, the curriculum, the policy of the programme, achieved intended learning outcomes and students' experiences with the study programme.

Chapter three of the Critical Reflection contains information about the programme, and it's intended learning outcomes. After discussing the layout of the programme, they describe elements of the programme for which students are not or less satisfied with. Furthermore, they also take a look at the outcomes of the National Student Survey 2018.

1.1.1 National Student Survey

Each year Studiekeuze123 carries out the *National Student Survey*[2]: a national survey to find out how satisfied students are about their study programme. Studiekeuze123 is a foundation created by students, higher education and the ministry of Education, Culture and Science, to collect and share objective study-choice-related information. (Studiekeuze123, n.d.-d) The NSE collects data and measures the satisfaction rate among students and their study programmes.

Participants of the survey are current students or graduates of a study programme who answer around 40 questions. The number of questions depends on participants' previous answers in the survey. The questions are clustered in several categories, ranging from *overall student satisfaction*, to *teachers*, to *preparation for the labour market*, etc. After the data is collected, the outcomes are presented online. The results of the National Student Survey are presented on a range from one to five, where one means not satisfied and five means satisfied. The outcomes could be used by students to compare programmes and to decide which study programme they would like to start. Next to that, it's also possible for researchers to use this data in their own study. (Studiekeuze123, n.d.-b)

Study programmes could use these results to see how satisfied their students are, for which the programme could take actions accordingly.

Applied Mathematics
The results of the NSE 2018 for the master programme Applied Mathematics are not below average, i.e., not below the average of three. However, the four categories which have the lowest score are (Studiekeuze123, n.d.-c):

- **Internationalisation**
  "Students' average satisfaction rating (scale from 1-5) about the degree to which the programme stimulates you and offers you the opportunity to orient yourself internationally, for example, the degree to which you are stimulated to study abroad of the degree to which the study programme pays attention to international aspects."
- **Study load**
  "Students' average satisfaction rating (scale of 1-5) about the study load, for example, the feasibility of deadlines for assignments, the degree to which the ECTS correspond to the actual number of hours you have to study."
- **Preparation for professional career**

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[2] In Dutch: National Studenten Enquête (NSE)

"Students' average satisfaction rating (scale of 1-5) about the degree to which you are prepared for your professional career, for example the contact you have with practice (internships)."

- **Internship and study programme**
  "Students' average satisfaction rating (scale of 1-5) about the quality of the internship supervision from the programme and the way in which you are prepared for your internship."

Table 1 NSE 2018 results; the four lowest scored subjects for the AM programme together with their satisfaction rate presented on the website, and the rate, standard deviation calculated based on the NSE Dashboard, together with the number of students who rated the statements

NSE 2018	Satisfaction rate available on the NSE Dashboard	Rate calculated by the author with the data available on the NSE Dashboard (rounded up)	Standard Deviation	Number of student answer
Internationalising	3.4	3.18	0.6629	34
Study load	3.6	3,15	0.6477	34
Preparation for professional career	3.4	3,02	0.7362	35
Internship and study programme	2.5	2.5	0.8062	10

Shown in the table above, the NSE 2018 results for the programme Applied Mathematics has a 2.5 for 'internship and programme'[3], which is below average. Lopuhaä interpreted this score as: '[the students'] satisfaction with the support received from the programme in preparation for the internship is low.' (2019, p. 22) Doing an internship is mandatory and is a way to familiarize with the professional career outside the TU Delft. In addition, 'preparation for professional career' is also one of the lowest scores. From this, the survey is interpreted as insufficient preparation for professional career offered by the programme. (Lopuhaä, 2019)

From the 10 respondents, 6 students scored below average. Next to that, when observing preparation for professional career, only 6 out of 35 students scored below three. As Lopuhaä (2019) mentioned in the Critical Reflection, the students are not unanimously satisfied, so further research should be done to find out why this is the case and what could be done to prepare them better.

1.2 Problem Statement

Students who are currently following the master programme Applied Mathematics or graduates from the study programme say they're not fully prepared for their professional

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[3] This is the preparation for the internship provided by the programme

career which is mentioned by Lopuhaä (2019) and the NSE (Studiekeuze123, n.d.-c). The study programme offers a mandatory internship, which is a way "to gain experience as a mathematician in a non-mathematics environment." (Lopuhaä, 2019, p. 20) The 'Internship and Programme' part on the NSE 2018 scored a 2.5, which is below average. Overall, the programme focusses on technological depth of Mathematics, but may lack preparing students for their career. Students, graduates and the programme acknowledge a gap between programme and professional practice. For this reason, the aim of this thesis is to find a solution which could narrow that gap.

1.2.1 Adaptability

Adaptability or adaptivity is a competency which allows people to settle more easily in a new and unfamiliar environment. (Carbonell et al., 2014; Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000, 2006; Savickas, 1997) When AM graduates are still studying at the university, the environment is familiar and they do not necessarily need adaptability to get around, as they could predict what will happen and what is expected of them. However, when they enter a work environment, which is new and unfamiliar, adaptability could help them start their career more smoothly. In an article written by Schwartz et al. (2005), they developed a preliminary "learning and performance space that differentiates two dimensions of transfer — innovation and efficiency." (p. 2) When focused on efficiency, people rely on their routine behaviour, and become routine experts. However, the problems people encounter in real life might be totally different from what they are used to, so they cannot rely on the skills and knowledge they normally use. On the other axis is innovation. People who are high on efficiency and on innovation are adaptive experts. Schwarz et al. say: "people who are optimally adaptive can rearrange their environments and their thinking to handle new types of problems or information." (Schwartz et al., 2005, p. 30)

We would like to find out how AM graduates could be more adaptive to start their career more smoothly, or more precisely, what inhibits or enables them to be adaptive in activities at their job. For this reason, the concept adaptability is chosen to be the main concept of this thesis.

1.3   Research Questions

The aim of this research project is to create a tool which allows the MSc programme Applied Mathematics to prepare their graduates to become as adaptive as possible for their future professional job.

Therefore, the main question (MQ) is

How could the MSc Applied Mathematics programme at the TU Delft prepare the AM graduates for the start of their professional career by including adaptability in the curriculum?

which is followed by 5 sub-questions (SQ):

1. How does the programme and other responsible departments prepare AM graduates for their professional career?
2. What barriers and facilitators do AM graduates encounter to adapt to activities at their job?
3. How does the programme help students to learn to adapt to situations related to the professional career? What kind of courses do they offer to do so?
4. What type of tool could help the programme prepare AM graduates to be adaptive in the first 3 years of their professional career?
5. How does this tool contribute to graduates professional career preparation (with the focus on adaptability)?

In the next section, the research methods used will be described.

1.4   Research Methods

To answer the research questions, we use a mixed method approach. Table 2 presents the methods used per sub question.

Table 2 Overview of research methods used to answer the sub-questions per chapter

	Semi-structured interviews with staff members of the programme, CH and Career & Counselling Services	Semi-structured interviews with alumni	Survey	Literature review on adaptability	Literature review on online tool development	Semi-structures interviews with staff members
SQ1: How does the programme and other responsible departments prepare AM graduates for their professional career?	O					
SQ2: What barriers and facilitators do AM graduates encounter to adapt to activities in their job?		O	O	O		
SQ3: How does the programme help students to learn to adapt to situations related to the professional career? What kind of courses do they offer to do so?	O					O
SQ4: What type of tool could help the programme prepare AM graduates to be adaptive in the first 3 years of their professional career?	O	O	O	O	O	O
SQ5: How does this tool contribute to graduates professional career preparation (with the focus on adaptability)?				O	O	O

Firstly, interviews with staff members of the AM programme, who play an important role in the programme outline, were held to answer SQ1. Other important departments/organizations within the TU Delft such as the Career & Counselling Services and the study association Christiaan Huygens (CH) were also interviewed. These interviews obtained what kind of preparation is offered to AM students' professional career by the programme and other departments at the university. The Critical Reflection was also analysed. The Critical Reflection is a document in which the programme is evaluated, which is used as a starting point for the visitation where a team of experts assesses the programme. Next to that, the interviews also discussed the NSE results and the interviewees view on that.

Secondly, interviews with alumni were conducted to gain insights on their experiences in the labour market, about their experiences with the programme, and more specifically with the programme's offered preparation for their professional career. Students shared what they encountered during their internship, but also their experiences with specific courses that helped them perform better at their current job. The interviews described situations that were difficult or were different from what they were used to at the programme. From these situations, a couple barriers and facilitators of the adaptive competencies were obtained, which will be explained in more detail in Chapter 5 and 6. Additional barriers and facilitators from literature were also found. The interviews were thus used to answer SQ2 partially.

Thirdly, a survey was created to further investigate whether the found barriers & facilitators from the interviews were also perceived by other graduates, and which ones were most applicable for specific competencies. The results obtained information about what enables or inhibits students to be adaptive at their current job. The survey was used to obtain a complete answer for SQ2.

Finally, interviews with staff members of the Master Programme Applied Mathematics were held to answer SQ3. Next to that, literature on motivation and technology acceptance was used to develop the advice for the master programme Applied Mathematics at the TU Delft, and to answer SQ4 and SQ5. The advice will help students become more adaptable. A preliminary version was discussed with staff members of the programme. The final advice could narrow the gap between programme and labour market a bit more.

1.5 Thesis outline

In this thesis, we first present the context of this thesis i.e., the preparation for the professional career offered by the programme and other departments at the university. Here, we interviewed several departments about their offered preparation. Chapter 2 answers SQ1. Chapter 3 presents the theoretical foundation of this thesis, where the concepts adaptability, adaptive expertise and career adaptability are explored. After describing the theoretical foundation of this thesis, Chapter 4 presents the theoretical framework with the learning outcomes of the master programme Applied Mathematics at the TU Delft. The Chapter 5 discusses the barriers and facilitators of a couple adaptive competencies found in the interviews. These items together with the theoretical framework were used to develop a survey. Chapter 6 presents the findings of the survey, and answers SQ2 completely. Chapter 7 answers SQ3, SQ4 and SQ5, for which a tool was developed on how to include adaptability in the curriculum.

2 Preparation Professional Career by the University

TU Delft's goal is to create engineers who are able to solve the world's problems technological. (*TU Delft Vision on Education*, 2017) They expect their graduates to be have skills like "mastery of scientific foundation of engineering", "analytic & modelling skills", but also "ability and attitude to adapt to changing conditions and environments ('they have learned to learn')" and "ability for effective inter- and multidisciplinary teamwork in international and culturally diverse environments". (*TU Delft Vision on Education*, 2017, p. 8) From this, one may say that the university also focusses on students who are able to perform well when the environment changes, or when they enter new, diverse environments. Overall, the university pays attention to students' professional career, as they create engineers who are able to solve world's problems in their future job career. (*TU Delft Vision on Education*, 2017)

This section explores the university's offered preparation for graduates' professional career, from three different angles: The Master programme Applied Mathematics, Career & Counselling Services, and the Study Association Christiaan Huygens (CH). The three groups interviewed all have some responsibility in preparing students for their professional career, all from different angles, motives and such. The master programme Applied Mathematics prepares their students for their professional career (Lopuhaä, 2019), by offering a mandatory internship as part of student's master programme. Besides, the TU Delft also has a Career & Counselling Services, a centre for students and young alumni, who would like to better prepare themselves for their future career. The Career & Counselling Services offers several workshops, trainings and activities, where students and alumni work on their professional development. The study association Christiaan Huygens also plays an important role in students' professional development, as they also offer career-related activities.

The programme, Career & Counselling Services and the study association all help students and graduates for their future professional career. For this reason, six active staff members were interviewed to find out what they think about the National Student Survey results and how they prepare their students for their professional career.

With the interviews and the NSE 2019 results, an answer to sub question 1 is obtained.

2.1 Methodology

2.1.1 Semi-structured interviews

Interviews were held to explore the preparation offered by several the Master Programme as well as other departments responsible for preparing students for their professional career, such as the study association and Career & Counselling Services TU Delft. Next to that, the interviews were also used to gain understanding of how these departments look at preparation for professional career and to gain insights on potential problems. Interviews are a good method to answer SQ1, because it allows us to go more into depth, in comparison to quantitative methods. For this reason, the interviews were semi-structured, which means that questions were developed beforehand, but still allowed us to ask follow-up questions based on the answers of the interviewee. The first interview with a staff member at the programme and the interview with a staff member at the Career & Counselling Services were not recorded. However, notes were taken during the interview, from which a short summary was written.

The other four conducted interviews with staff members of the programme (2 interviews) and the study association (2 interviews) were recorded. The recorded interviews with staff members of the programme were transcribed like a summary with quotes and not word-for-word. The interviews with the study association were transcribed word-for-word. The summary's and the transcripts were used to obtain an answer. The transcripts were not coded but were used to create an overall summary of their opinion. Dutch versions of the interview protocol are presented in Appendices *A. Interview Protocols (Dutch)*.

2.1.2   Analysing Documents

The National Student Survey was one of the starting points of this thesis. For this reason, we decided to explore the results of the NSE and discuss what the programme's view on the matter is. Therefore, we first discussed the 2019 NSE results, and used the Critical Reflection to determine the programme's interpretation of the NSE results. The Critical Reflection is written by the Director of Studies, Dr. Rik Lopuhaä, with the help from the faculty's Education and Student Affairs and students. The Critical Reflection used the NSE 2018 results. Afterwards, we discussed the interview results with staff members of the programme, Career & Counselling Services and the study association CH.

2.2   Outcomes

2.2.1   The National Student Survey

As was described in the Introduction, Studiekeuze123 sends out the National Student Survey, an annual questionnaire for students' and graduates' satisfaction about their study programme. The Master Programme Applied Mathematics participates in this survey, just like all the other programmes at other universities.

The Critical Reflection (Lopuhaä, 2019) mentioned that the graduates are not unanimously satisfied with the preparation offered. This conclusion was based on the NSE satisfaction rate[4] on 'preparation for the labour market'. For this reason, we investigated the four lowest satisfaction rates of NSE 2019, which are found in Table 3.

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[4] The Critical Reflection used the results of NSE 2018

Table 3 The four lowest NSE 2019 results for the Applied Mathematics Master Programme; the four lowest scored subjects for the AM programme together with their satisfaction rate presented on the website, and the rate, standard deviation calculated based on the NSE Dashboard, together with the number of students who rated the statements

NSE 2019	Satisfaction rate	Rate calculated by the author (rounded up)	Standard Deviation	Number of student answer
Internationalising	3.5	3,25	0,829	36
Study load	3.7	3,44	0,767	41
Preparation for professional career	3.7	3,45	1,005	42
Internship and study programme	-	3,00	1,195	14

Table 3 presents the satisfaction rate presented at Studiekeuze123, and satisfaction rate and standard deviation calculated by the author with use of the NSE Dashboard. As shown in the table above, the NSE results for the programme Applied Mathematics has no score for *Internship and Programme*[5]. No score means that not enough students no or too little trustworthy information available to score this part. (Studiekeuze123, n.d.-a) Doing an internship is mandatory and is a way to familiarize with the professional career outside the TU Delft. In addition, *Preparation for Professional Career* is also one of the lowest scores. As shown in Table 1, both scores have increased between the year 2018 and 2019. However, the standard deviation of both scores increased, suggesting that student's satisfaction vary a bit more than before.

When observing the NSE Dashboard, an interactive public benchmark file, *Internship and Programme* received a 3.1 and is based on the information provided by 14 respondents. From the 14 respondents 37% scored below average. Next to that, when observing preparation for professional career, only five out of 45 students scored below three.

As shown in the Table 3 the lowest is 3.5 which is not below average (average is three). When considering the standard deviation, nothing spectacular is shown. *Internship and study programme* does not have a score available on the website about the Applied Mathematics master programme[6], because not enough students rated the statements or too little trustworthy information is available to score this part. (Studiekeuze123, n.d.-a) The standard deviation for this part is higher than all the others, but that was already expected because the information was not 'trustworthy'. As shown in

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[5] This is the preparation for the internship provided by the programme

[6] https://www.studiekeuze123.nl/opleidingen/10642-applied-mathematics-technische-universiteit-delft-wo-master

Table 3 as well, the ratings on the website are different from the ones calculated with the NSE Dashboard. The NSE was contacted about it, but they failed to reply.

Participants were asked to rate several questions about preparation for the labour market and the alignment between study programme and labour market. The questions are presented in Textbox 1, which is translated from Dutch by the author. The ratings of *Preparation for professional career* and *Internship and study programme* are probably based on the statements presented in Textbox 1. However, it is not entirely sure if these statements are one-on-one related to the topics.

National Student Survey 2019

Preparation for the labour market

Please rate to what extent you are satisfied with the following statements (1 to 5; 1 is extremely dissatisfied; 5 is extremely satisfied; 6 is not applicable).

- Gaining skills for professional practice
- The practical orientation of your education
- Contact with the professional practice (e.g., internships, guest speakers, assignments for third parties)

Internship (only if students did an internship)

Please rate to what extent you are satisfied with the following statements (1 to 5; 1 is extremely dissatisfied; 5 is extremely satisfied; 6 is not applicable).

- The quality of the internship guidance from the training course
- The preparation for the internship by the training
- The guidance at your internship by the company or institution where you are doing your internship.
- What you learned during your internship
- The connection of the internships with other education

Textbox 1 Statements of the NSE 2019 on preparation for professional career and internship and study programme

Lopuhaä (2019) mentioned the NSE results of 2018 in the Critical Reflection (2019) and tried to explain the ratings. Lophuaä mentioned other points of attention obtained from meetings with alumni industrial advisory board and their own conducted survey. Firstly, Lopuhaä mentioned that their students are "less [satisfied] about learning scientific writing." (p. 20) So, a mandatory course 'Scientific Writing' (3 ECTS) was added. Secondly, students' "satisfaction with the support received from the programme in preparation for the internship is low." (p. 22) The alumni on the industrial advisory board suggested that their expectations and the support provided by the internship coordinator is different. The programme suggested to better communicate with their students about the available support, and said they would discuss the matter with their students in Master Information Meetings[7]. Finally, Lopuhaä mentions that the students were also less satisfied about the study load, as the feasibility to finish deadlines

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[7] Master Information Meetings (MIM) are meetings, in which the master coordinator shares information about the programme and helps student by answering their questions. Information about the internship is also presented there. These meetings are not obligatory.

has dropped. (Lopuhaä, 2019) The programme decided to find a solution for this and will take measures accordingly.

Additionally, the programme also mentions that students are not so "satisfied with the attention paid to communication and collaboration." (p. 20) and that students were also not all satisfied with the programme's preparation for professional practice and attention paid to presentation and communication skills. (Lopuhaa, 2019, p. 22) However, no solutions for these points of attention were presented.

As described above, the NSE results improved from 2018 to 2019. However, the standard deviation increased from 2018 to 2019 suggesting that the students' satisfaction vary more than before. Next to that, when considering the National average of the NSE, the AM master programme at the TU Delft has the same average as the national for *Preparation for Professional Career*. For *Internship and Programme* the NSE dashboard showed a score of 3.00, which is 0.4 below average.

To further understand the results and the interpretations of it, three staff members of the master programme were interviewed. The results are presented in the next subsection.

2.2.2 The master programme Applied Mathematics

Three staff members of the Master programme Applied Mathematics were interviewed to determine the programme's opinion on the offered preparation for their students' professional career. Each staff member has an important role in the programme's education outline.

Each interviewee said it's interesting to see why participants of the NSE give a low score on *Preparation for Professional Career* as well as for *Internship and Programme*. The interviewees all have different opinions on these scores.

Staff Member 1 believes that students are more prepared for their professional career than is stated in the NSE, as the students are obliged to follow an internship or conduct a master thesis at a company. The internship is mandatory, and serves as a way to familiarize yourself with the professional career, as is written in the Critical Reflection. (Lopuhaä, 2019)

Staff Member 2 says that during an internship the students learn that 'mathematics is a tool, not the goal.' He believes the low scores is due to the programme itself, as it's more focussed on developing a deeper understanding of mathematics. The level of mathematics most students use in their company job is way less than they are used to. Next to that, Staff Member 2 also believes that every graduate encountered or will encounter a culture shock.

Staff Member 3 agrees with Staff Member 2, and says that everyone who enters their professional career will encounter a culture shock, which the programme wants to avoid by offering a mandatory internship. When asked about the NSE scores, he immediately responded with "But what does the student expect? What kind of preparation do they expect?"

Overall, they all mention that the internship is necessary for students as it prepares them for their professional career, and do not mention other courses or relevant workshops students could attend to. For this reason, the internship is mandatory. However, the results of the NSE show that the programme offers insufficient help and does not prepare them for the

internship, which could result in graduates not being fully prepared for their professional career. It is unclear what kind of help students expect from the programme.

All interviewees explained when talking about 'preparation for professional labour market', that the students are not prepared for the work life, i.e., going to a nine-to-five job, working as a project member, working with deadlines and not receiving regular feedback.

The Critical Reflection (2019) mentions that next to the internship, the study association also provides activities to gain more information about future career possibilities.

2.2.3 Study Association Christiaan Huygens

The programme Applied Mathematics has a study association called Christiaan Huygens (CH), which is also the study association for Computer Science. CH aims to carry out and offer solutions to study-related needs of their students, and to create a bond with students and alumni. (*Study Association Christiaan Huygens | About*, n.d.) CH organizes workshops, and trainings for students to prepare themselves for the labour market. At these workshops, students learn more about soft skills, like negotiation, pitching, job application, CV checks, etc. Next to that, they are also co-host of the Delftse Bedrijven Dagen (DBB), where students are able to join trainings and get familiar with the job application procedure. At the DBB, students could also talk to recruiters and companies. CH also offers company visits, where a group of students visits a company and get familiar with the environment. They sometimes also do a project there.

Staff Member 4, a CH board member, believes students do not know what they would like to know career-wise, because when they asked if they have any remarks about the career-related activities, no student commented. CH tries to set-up a network event with alumni for their students to know more about graduates' experiences or to find an internship of master's thesis project, which the interviewee believes is very valuable. The Staff Member also said there is a limit to what they could do to prepare students. They host events for students to know more about their professional career, they promote these events, and it's up to the student to decide to join or not.

Staff Member 5, another member of the CH board, believes that there is a split when it comes to students being prepared for their professional career. A part of the students goes to career-related events and another part does not. Staff Member 5 believes that students are more prepared when they go to these events.

Overall, Staff Member 4 and 5 both believe that it is very unclear what the possibilities for Applied Mathematics students are after graduating, and which jobs are related to their master track. For this reason, they started hosting a mathematics career orientation day, where students could meet companies who are interested in specific specialisations of the master programmes, and where students could find more about the labour market and to see a couple of possible career paths.

When talking with the study association about preparing students for their professional career, they highlight two different aspects. Both link preparation with not knowing what is possible after graduating, and one Staff Member also talks about going to workshops about job application, CV, negotiation, and more.

CH organizes many activities, but the TU Delft also has a general department that also offer these kinds of career-related events.

2.2.4   Career & Counselling Services

The TU Delft has a Career & Counselling Services department, which offers personal and career-related help for students and alumni. Their goal is for students to develop a successful sustainable career goal, by offering workshops on self-reflection, generic skills, and more.

Staff Member 6, an employee at C&C, explains that Career & Counselling also offer self-analysis workshops for students to think about their goal and their future job. At the workshop, some students find out that they do not possess specific skills yet to apply for the job they like, and could follow additional courses or workshop to enhance that skill.

Overall, Career & Counselling Services offer students help to find the right job by offering job application trainings, self-analysis workshops, CV & motivation letter training, strategies to find a job, and more. (*Career & Counselling Services | Managing Your Career*, n.d.) They also offer events to meet with alumni.

From this interview, it was found that the Career & Counselling Services focus on offering the right training to find the right job, and enhance self-awareness and prepare students for job applications, next to, offering possibilities to meet with alumni and companies.

2.2.5   Different Definitions of preparation for professional career

After interviewing staff members, CH and Career & Counselling Services, four different outlooks on 'preparation for professional career' are found, which are summarized in Table 4. We see that there are different views on preparing students for their professional career, which could be divided in the following four categories:

	Outlook on preparation for professional career
Staff members of the Applied Mathematics Programme	When describing 'preparation for professional labour market', the staff members talk about the work life, i.e., going to a nine-to-five job, working as a project member, working with deadlines and not receiving regular feedback, and believe that students are not prepared for this, and that the programme does not prepare them for this.
Study Association	When talking with the study association about preparing students for their professional career, they highlight two different aspects. Firstly, they link preparation with not knowing what is possible after graduating, and secondly, one Staff Member talks about going to career-related training such as job application trainings, CV-check, negotiation workshops, etc.
Career & Counselling Services	The Career & Counselling Services focus on offering training to find the right job, enhance self-awareness and prepare students for job applications, next to, offering possibilities to meet with alumni and companies.

The four different outlooks are listed below:

1. Students are not prepared, because they are not familiar with 'working'.
2. Students are not prepared, because they did not go to career-related events, training or workshops, such as the ones offered by the study association or Career & Counselling Services
3. Students are not prepared, because they lack certain skills and knowledge, like self-awareness, negotiation, etc.
4. Students are not prepared, because they do not know how the future professional career looks like and what type of job they could do after graduating.

2.3 Chapter Conclusion

This section explores the preparation offered for students to prepare themselves for their professional career to answer SQ1.

> 1. *How does the programme and other departments responsible for the preparation of students' professional career prepare AM graduates for their professional career?*

The staff members of the study programme all mention that the internship is offered to prepare students for their professional career. At the internship, the students get familiar with the working life, learn that mathematics is a tool and not the goal, and prepare themselves for the shock they would have otherwise encountered after graduating. But is this enough?

The study association and Career & Counselling Services also play an important role in the preparation for students' professional career. They both offer activities about career-related topics, such as application, self-awareness and negotiation, to prepare students for their professional career, but it's up to the student to decide whether they join or not.

From this, we conclude that the programme believes the internship is the most important aspect of the programme in which students could prepare themselves for their career. Next to that, students could also join lectures and events hosted by Career & Counselling Services or the study association, where they could learn more about their professional career, and what is needed in the process of applying.

In the next section, we will explore the concept adaptability to develop a Theoretical Framework for this thesis. This framework will be used to find out what kind of items inhibit or enables the graduates to display forms of adaptability which they need to perform their job.

3 Adaptability

Adaptability or adaptivity is the ability to settle more easily in a new and unfamiliar environment. (Carbonell et al., 2014; Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000, 2006; Savickas, 1997) The concept adaptability in the workplace is investigated by several authors. (Charbonnier-Voirin & Roussel, 2012; Monteiro et al., 2019; O'Connell et al., 2008; Ployhart & Bliese, 2006; Pulakos et al., 2000, 2006; Savickas, 1997; Savickas & Porfeli, 2012)

In this section, we will explore the concept *Adaptability in the workplace* and develop a theoretical framework. This framework is used throughout this thesis, and is used to create the survey, which is explained in more detail in Chapter 6. We first start with the methodology.

3.1 Methodology

3.1.1 Literature review Adaptability in the workplace

A literature review was conducted to find articles on *Adaptability in the workplace.* SCOPUS and World of Science were used to perform a simple literature review. With the articles, a definition for *Adaptability for AM graduates in the workplace* was developed*.* In order to do so, articles about adaptability, adaptivity and flexibility were found. The exact search terms are presented in Appendix H. In total, 70 articles were obtained from which four duplicates were removed, and another three articles were deleted because they were published before 1990. After that, several articles were removed based on their title, and 36 articles were left. The deleted articles were not about adaptivity, flexibility, professional career or development, or were about something unrelated from adaptability, such as electronic learning environment, online training, some technological phenomenon, trait and error, organisational resilience, stress resilience or work flexibility. An example of an article not used was about how to change one's workplace sedentary behaviour, which is 'sitting behind a desk', by using a novel mobile phone application. (Cole et al., 2015) Another article was about economic resilience, and how to assess individual buildings' loss of functionality after an earthquake. (Mieler & Mitrani-Reiser, 2018). Afterwards, another 20 articles were removed based on their abstracts. At the end, 17 articles were left which were read by the author. Again 12 articles were removed for many reasons: some of them did not explain the concept adaptability, or did not use adaptability to describe the gap between education or workplace. These articles do say that adaptability or flexibility are needed to be successful 21st century engineers, but do not explain how to become adaptive and flexible. Other articles described organizational resilience (Fannoun & Kerins, 2019), trait resilience (Maltby et al., 2016), leadership development (Craft et al., 2014), or resilience development among (Wright et al., 2019). After reading the articles, only five articles were relevant to use for this thesis. Next to reading the articles found in the literature review, additional literature provided by the course SL3081 Professionalization in the Science Education and Communication master programme at the TU Delft was also used. Other additional articles were found by 'snowballing'. These articles were chosen based on if they discussed adaptability, adaptive expertise, or one of the other concepts, combined with workplace, work and professional career. Below the flow of the literature review is presented.
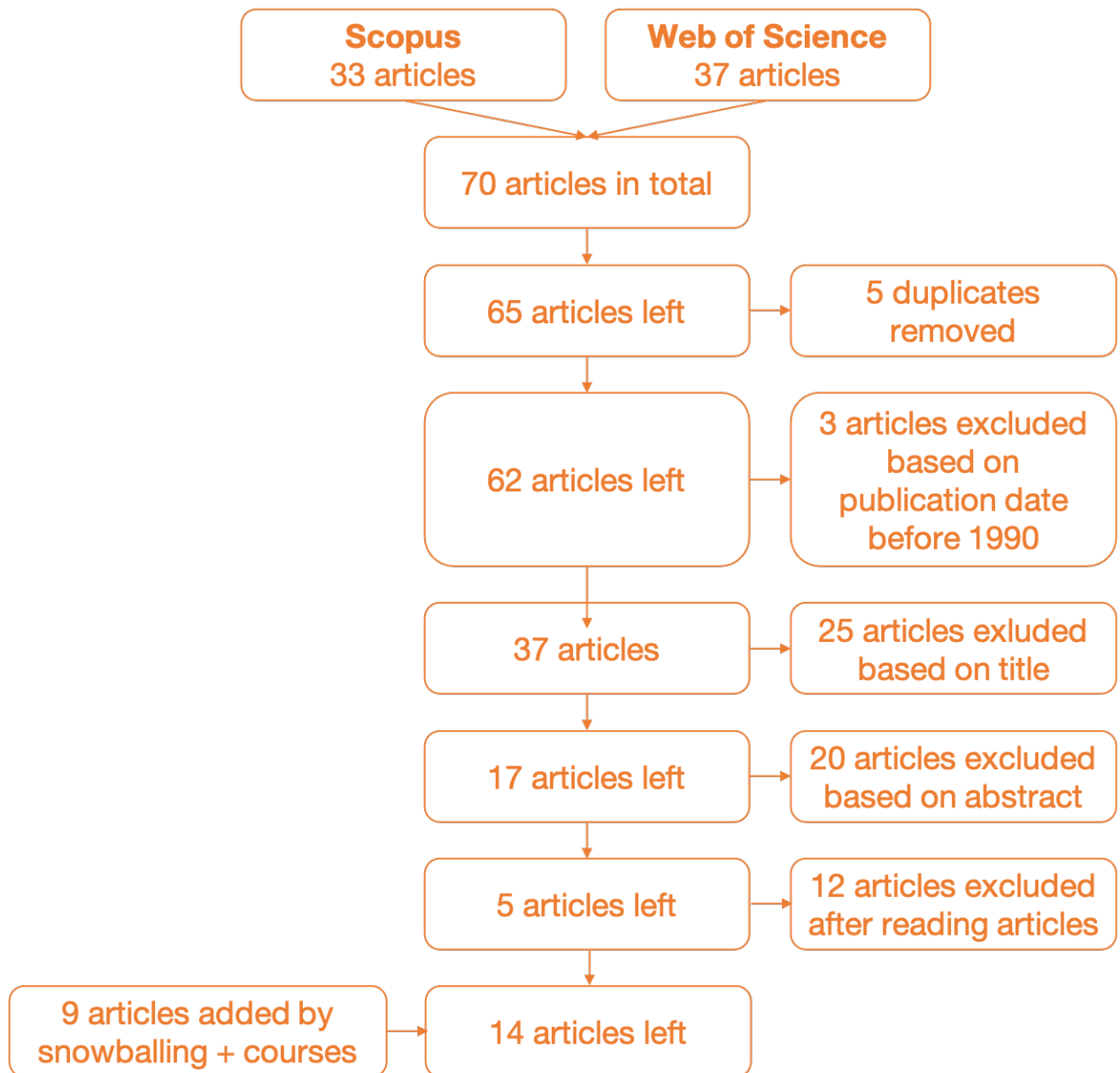
Figure 1 Overview of the performed literature review in Scopus and Web of Science to obtain articles about adaptability in the workplace

3.2 Outcomes

3.2.1 To Adapt

Adaptability, adaptation, adaptivity, adapting are all words with different meaning which come from the word 'adapt'. To adapt means (1) 'to make suitable to requirements or conditions; adjust or modify fittingly', and (2) 'to adjust oneself to different conditions, environment, etc.' (*Adapt | Definition of Adapt at Dictionary.Com*, n.d.).

Savickas & Porfeli (2012) and Savickas (1997) defined the following concepts as follows:

Table 5 Different definitions of 'Adapt*' proposed Porfeli & Savickas (2012)

Adapt*	Definitions
To adapt	"To fit or to join" (Savickas & Porfeli, 2012, p. 661)
Adaptation	"Consequence of adapting" (Savickas & Porfeli, 2012, p. 662)
Adapting	"Performing adaptive behaviours that address changing conditions" (Savickas & Porfeli, 2012, p. 662)
Adaptability	"The quality of being able to change, without great difficulty, to fit new or changed circumstances." (Savickas, 1997, p. 254)
Career Adaptability	"An individual's resources for coping with current and anticipated tasks, transitions, traumas in their occupational roles that, to some degree large or small, alter their social integration." (Savickas & Porfeli, 2012, p. 662)

In the case of the workplace, several authors developed definitions, theories or more, for each of these words. Below, we discuss the terms which were most mentioned in literature about the workplace: adaptive expertise, adaptive performance, individual adaptability, and career adaptability.

3.2.2 Adaptive Expertise

Adaptive expertise was first mentioned by Hatano & Inagaki (1986). They investigate spontaneous expertise and propose three related issues referred to children's development. Hatano & Inagaki define adaptive expert as: "those who not only perform procedural skills efficiently but also understand the meaning of the skills and nature of their object." (p. 28) People can become flexible and adaptive. Next to adaptive expertise, they also mention routine expertise. People who become routine experts know how to perform a skill only if the environment stays the same. The problems are solved fast, efficient and accurate, but when faced with a novel problem, routine experts miss flexibility and adaptability. They say the differences between adaptive and routine expertise lies on (1) the problem the individual is working on, because more randomness in the problem leads to changing behaviour and adaptive expertise, while familiar problems do not demand changing behaviour, (2) the context of the problem, and if rewards are present, because without rewards, the individual

develops conceptual knowledge [8] by means of playing, while rewards could inhibit an individual to change one's behaviour, as they might lose the reward, and (3) the environment and if understanding the behaviour is of meaning for the environment.

Other authors who discussed adaptive expertise are Schwartz et al. (2005). They did research on transfer of knowledge and tried to a find a framework for it. They proposed a preliminary "learning and performance space that differentiates two dimensions of transfer — innovation and efficiency." (p. 2) People who are high on efficiency but low on innovation are routine experts. A benefit of high efficiency is that "it includes a high degree of consistency (lack of variability) that maximizes success and minimizes failure." (p. 28) However, as they are very good at solving specific problems, they lack continuous learning and dealing with novel problems. (Carbonell et al., 2014) People who are high on efficiency and on innovation are adaptive experts. These people handle novel problems by reorganizing their thinking and the setting they're in. Schwartz et al. also note that innovation sometimes involves moving away of what is most efficient for the individual or the organization. (2005)

Carbonell et al. (2014) investigated the characteristics of adaptive expertise and how to facilitate it. They define adaptive expertise as "The ability to quickly get accustomed to change […]" (2014, p. 15) Adaptive expertise has all the components of routine expertise, i.e., they both have the same knowledge in particular domains and know how to deal with familiar situation, but differ from each other when it comes to dealing with novel problems

3.2.3 Adaptive Performance
Hatano and Inagaki's work (1986) has been mentioned in literature a lot (e.g., Carbonell et al., 2014; Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000, 2006; Schwartz et al., 2005) Pulakos et al. (2000) looked into the concept of adaptability in the workplace, more precisely adaptive performance in the workplace. They defined job adaptive performance requirements. The identified components are more or less relevant to specific jobs. The participants came from different jobs including 'service jobs, technical jobs, support jobs, law enforcement jobs, and several different types of military jobs, as well as supervisory and managerial jobs.' (p. 615) Pulakos et al. say that examples of adaptive performance on the job are "*situations in which individuals modified their behaviour to meet the demands of a new situation or event or a changed environment.*" (p. 615) So, adaptive performance refers to adapting one's behaviour within a new or changed environment. As they refer to 'situations' indicating the past, this indicated that adaptive performance is the result of overcoming the change in the environment, which was also mentioned by Carbonell et al. (2014) Next to that, the dimensions of adaptive performance say something about the 'types' of adaptability, or when adaptability was required.

When researching for a precise definition of adaptive performance, an article written by Charbonnier-Voirin & Rousell (2012) was found. They developed and evaluated a scale measuring five dimensions of adaptive performance. In this article, adaptive performance is

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[8] Conceptual knowledge is: "when the performer has knowledge representing more or less comprehensively the nature of the object of the procedure and its surrounding "world". This knowledge gives meaning to each step of the skill and provides criteria for selection of possible alternatives for each step within the procedure. It may even enable him/her to invent new procedures and/or make new predictions." (Hatano & Inagaki, 1986. p. 28)

"the ability of an individual to change his or her or his behaviour to meet the demands of a new environment." (p. 280) Charbonnier-Voirin & Rousell (2012) used the eight dimensions created by Pulakos et al. (2000) to develop the scale. The conducted exploratory factor analysis resulted in a five-factor solution. A couple of the eight dimensions were combined.

3.2.4 Individual Adaptability

Ployhart & Bliese (2006) created the Individual ADAPTability (I-ADAPT) theory, where they proposed a theory of individual differences in adaptability, because they believed there was little work done on the nature, structure and function of adaptability in social and work environments. They say: "*Individual adaptability represents an individual's ability, skill, disposition, willingness, and/or motivation, to change or fit different task, social, and environmental features.*" (2006, p. 13) Ployhart & Bliese mention that individual adaptability is a stable construct which affects a person's interpretation and responsiveness to a changed situation, rather than something that is required by a changed environment or situation or only something that arises when the situation has changed. Next to that, they also note that an individual could either change the environment, alter oneself or the elements in between. Thus, individual adaptability is not only about a person changing oneself to fit to a changed situation, but an individual could also change the environment one is in. An example of this could be of a graduate adapting him or herself within a new of changed environment, or changing the environment for him, like switching tasks.

I-ADAPT is based on theories from several other authors, like Pulakos et al. (2000) and Pulakos et al. (2006).

O'Connell et al. (2008) explored personal adaptability in the workplace. Career adaptability "is important in dealing with change and taking charge of career direction." (p. 248) They propose that three groups of factors are connected to personal adaptability, i.e., characteristics of the individual, the characteristics of the work environment, and the measure of human capital. They "propose that adaptability is shaped by a number of factors that are both internal and external to individuals." (p. 249) The groups and factors are shown in the figure below. After testing the model, they found that only gender, employability and education, and managerial support positively relates to personal adaptability.
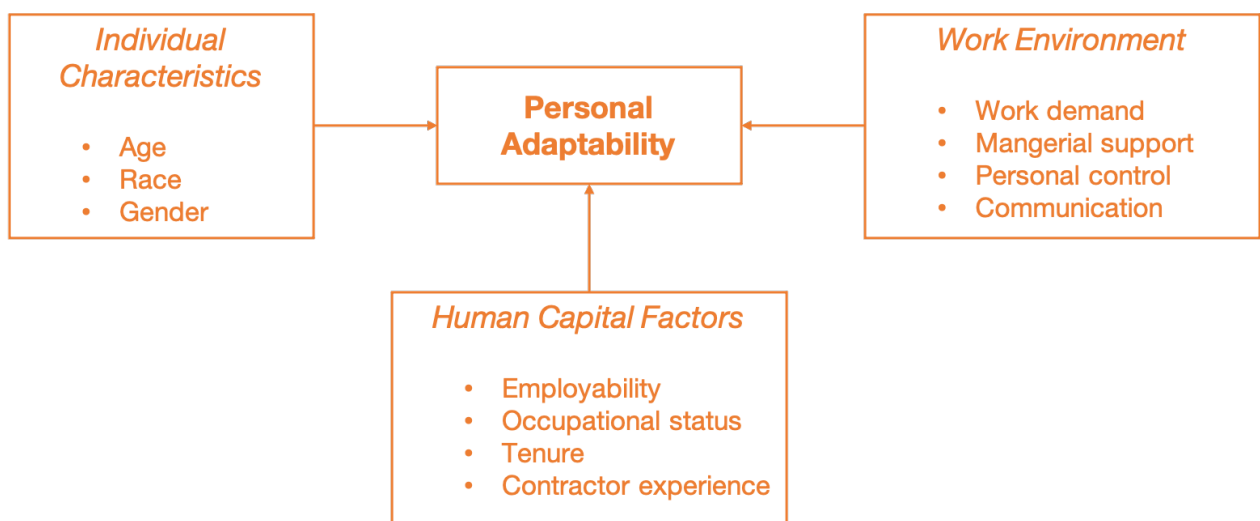
Figure 2 Model of antecedents of personal adaptability proposed by O'Connell et al. (2008)

3.2.5   Career Adaptability

Monteiro et al. (2019) investigated how career adaptability and university-to-work transition effects on employment status, for which they used the Career Abilities Scale created by Savickas & Porfeli (2012). Monteiro et al. (2019) used the definition of career adaptability from Savickas (1997) which is: *'the readiness to cope with the predictable tasks of preparing for and participating in a work role and with the unpredictable adjustments prompted by changes in work and work conditions.'* In the same article by Savickas (1997), they define adaptability as follows *"[...] the quality of being able to change, without great difficulty, to fit new or changed circumstances."* (p. 254) Monteiro et al. found that the career adaptability resources are similar before and after the university-to-work transition for graduates who get a job after graduating.

3.2.6   Resilience

Next to adaptability, the concept resilience is also mentioned in literature about adaptivity or adaptability when talking about facing stressful situations (Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000; Pulakos et al., 2006). Resilience is defined as '(1) the power or ability to return to the original form, position, etc., after being bent, compressed, or stretched; elasticity, and (2) ability to recover readily from illness, depression, adversity, or the like; buoyancy'. (*Resilience | Definition of Resilience at Dictionary.Com*, n.d.) The concept is mostly investigated in the context of mental health with patients, as mentioned by Friborg et al. (2003), Bennet et al. (2010), Bennet et al. (2018), Mallak & Yildiz (2016) and Mallak (2017).

Friborg et al. (2003), Bennet et al. (2010), and Bennet (2018) all focus on resilience in the context of mental health, which is not applicable for this research.

Mallak & Yildiz (2016) developed a Workplace Resilience Instrument (WRI) to measure workplace resilience of employees in how they approach work. They define resilience in the workplace as '*the ability for an employee to absorb energy from a stressful situation and to return to their original (or improved) condition once the stressor is removed*.' (2016, p. 6) Returning to original conditions relates to a change in behaviour. Mallak & Yildiz found four factors of workplace resilience, which are: Active Problem Solving, Team Efficacy, Confident Sense Making and Bricolage. The WRI could be a "useful tool for improving workplace resilience and helping employees achieve their potential." (2016, p. 25)

3.2.7   Dimensions describing Adaptability

Some of these authors created models or frameworks that describe adaptability more precisely. These models define adaptability in terms of variables, and are used to create a theoretical framework for this thesis.

In 2000, Pulakos et al. developed eight dimensions of adaptability in the workplace and discovered that "certain jobs may require greater amounts of adaptive behaviour than others" and that "different types of adaptive performance may be required in different types of job" (Pulakos et al., 2000, 618) The dimensions describing adaptive performance are in fact competencies.

Table 6 Dimensions of adaptive performance with their definitions proposed by Pulakos et al. (2006)

Dimension name	Dimension Definition (Pulakos et al., 2006, p.43)
Solving problems creatively	"Solve atypical, ill-defined, and complex problems"
Dealing with uncertain and unpredictable work situations	"Adjust and deal with unpredictable situations, shift focus, and take reasonable action"
Learning work task, technologies and procedures	"Anticipate, prepare for, and learn skills needed for future job requirements"
Demonstrating interpersonal adaptability	"Adjusts interpersonal style to achieve goals working with new teams, co-workers or customers"
Demonstrating cultural adaptability	"Performs effectively in different cultures learning new languages, values, traditions, and politics"
Demonstrating physically oriented adaptability	"Adjusts to various physical factors such as heat, noise, uncomfortable climates, and difficult environments"
Handling work stress	"Remains calm under pressure, handles frustration, and acts as calming influence"
Handling emergencies or crisis situations	"Reacts appropriately and decisively to life-threatening or dangerous situations"

Throughout this thesis, Pulakos et al. (2000) framework on adaptive performance will be used. Adaptability is a broad concept, for which authors have created different definitions and meanings for. Pulakos et al. is one of few who created a framework and divided the concept in smaller concepts, i.e., the eight dimensions. As we would like to find out how AM graduates could be more adaptive in their professional career, we could use a couple of these dimensions to find out if students have these competencies and on which of these competencies the programme should focus on more. Charbonnier-Voirin & Roussel (2012) developed a new scale to measure adaptive performance in the workplace, and combined a couple of Pulakos et al.'s dimensions and found five relevant dimensions.

3.3 Chapter Conclusion

This chapter described the theoretical framework for this thesis. Adaptability is useful when people enter a new environment, and is thus useful for AM graduates when they start working. Pulakos et al. (2000) described eight different dimensions of adaptability, which are adaptive competencies. We choose to work with the framework of Pulakos et al. (2000), because these dimensions were described in a bit more detail in their article, than it was by Charbonnier-Voirin & Roussel (2012).

Resilience is linked with Adaptability, as they both describe being able to withstand an adversity, e.g., a difficult situation such as entering a new work environment. Resilience is also mentioned in literature when talking about facing stressful situations, such as Pulakos et

al. (2000). We therefore believe that resilience is partially a part of adaptability. For this reason, resilience is not further used in this thesis, and we focus entirely on adaptability.

The theoretical framework is used to develop the survey, where we obtained the barriers & facilitators of these adaptive competencies, by first asking if they have this perceived competency. If they have it, we asked what helped them to have this competency, and if they do not have it, we asked them what they need.

In the next Chapter, we dive deeper in the master programme Applied Mathematics and find out which competencies are most applicable for AM graduates.

4 Adaptability for AM students at the workplace

Adaptability or adaptivity is the ability to settle more easily in a new and unfamiliar environment. (Carbonell et al., 2014; Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000, 2006; Savickas, 1997). In this chapter, we consider the learning outcomes of the Applied Mathematics programme, explore the definition of adaptability and find its link, to determine what adaptability competencies graduates should have after completing the master's programme.

As is presented in the Introduction, this thesis focusses on the Master Applied Mathematics at the TU Delft. The programme is thus a case study for the broader idea on how to narrow the gap between programme and the labour market.

This chapter explores the link with the master programme Applied Mathematics and the eight dimensions of Pulakos et al. (2000). Firstly, the learning goals of the master programme are presented, after which the variables were linked with the eight dimensions. Four dimensions were found to have links with the learning goals, and from this, a definition for *Adaptability for AM graduates in the workplace* was developed.

4.1 Methodology

The eight dimensions obtained by Pulakos et al. (2000) and the learning goals written in Lopuhaä (2019) were analysed independently to understand these things better. Afterwards, the dimensions were read by the author and links were found based on the text.

4.2 Outcomes

4.2.1 Learning goals of the AM master programme

The master programme Applied Mathematics covers both pure and applied mathematics. (Lopuhaä, 2019) It involves a broad range of mathematical subdomains from Analysis to Numerical Analysis to Optimisation. The programmes objectives are (1) "to provide students with a thorough knowledge of pure and applied mathematics", and (2) "to develop expertise in applying the methods and tools of mathematics to problems in science and engineering." (Lopuhaä, 2019, p. 11)

Next to the objectives mentioned above, the programme also educates their students to meet the exit qualification mentioned below (p. 13). A graduate MSc Applied Mathematics at TU Delft:

1. Is familiar with the existing knowledge in the field of mathematics and its applications, and is competent to extend and develop this independently by means of study.
2. Is able to develop his or her own mathematical knowledge and insights in a focused and methodological fashion.
3. Is able to develop and analyse mathematical models for problems from other disciplines and assess their usefulness.
4. Has a systematic approach, characterized by the application of mathematical theories and development of mathematical methods and models, has a critical attitude.
5. Has knowledge and understanding of mathematical and deductive reasoning necessary for and present in rigorous mathematical proofs and is able to apply this kind of reasoning generically.
6. Can work in a team and is able to communicate mathematical knowledge verbally and in writing to specialists and non-specialists.
7. Is aware of the relation between mathematics and its role in society and is able to integrate this awareness while considering technological and societal problems.

The programme used the criteria created by Meijers, Overveld, & Perrenet (2005), which are shown in Figure 3

Method		**Domain**	
4. a scientific approach		1. competent in one or more scientific disciplines	
specific for the sciences		*concerning existing knowleddge and artefacts*	
generically applicable		*concerning new knowledge and artefacts*	
5. basis intellectual skills	6. competent in co-operating and communicating	2. competent in doing research	3. competent in designing
individual	*with others*	*understanding*	*making*

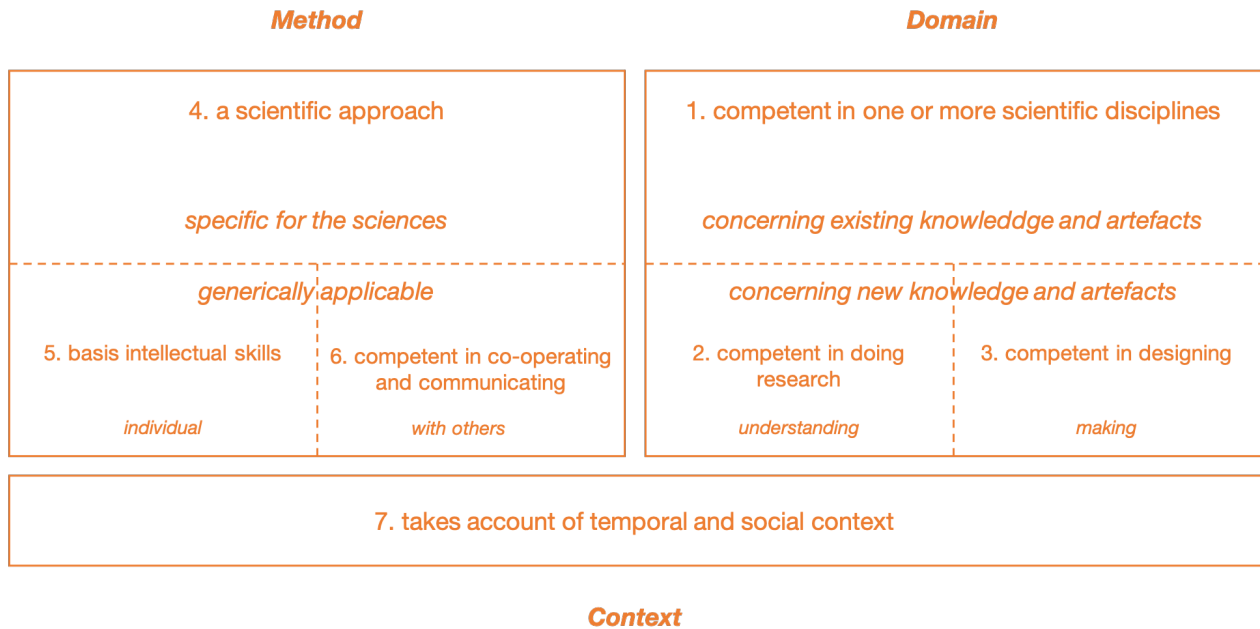| 7. takes account of temporal and social context |
|---|

Context

Figure 3 Criteria for academic bachelor's and master's curricula developed by Meijers, Overveld, & Perrenet (2005)

As presented before, adaptability is used as the major concept of this thesis. Before we develop a definition for *Adaptability for AM graduates in the workplace*, the variables and the master programme are connected with each other.

4.2.2 Competencies & Programme

The eight dimensions proposed by Pulakos et al. are eight competencies. Although, Pulakos et al. (2000) found links with specific jobs, some of these competencies could also be relevant to AM graduates' exit qualifications. As written previously, each AM student has to meet 7 exit qualifications when they obtain their master's degree.

Each of these qualifications were compared with the programme's exit qualifications, to find out which of these adaptive competencies are expected to be part of a graduate's list of competencies. They were linked by analysing the qualifications and competencies by the author herself.

1. **An AM graduate is familiar with the existing knowledge in the field of mathematics and its applications, and is competent to extend and develop this independently by means of study.**

As mentioned above, an AM graduate is competent to extent and develop 'knowledge' independently by means of study, which refers to 'Learning new work tasks, technologies and procedures'. This exit qualification is also about continuous learning, which is a characteristic of adaptive expertise (Carbonell et al., 2014; Pulakos et al., 2000).

2. **Is able to develop his or her own mathematical knowledge and insights in a focused and methodological fashion.**

This also links to *Learning work tasks, technologies and procedures*, but also with *Solving Problems Creatively,* as AM graduates develop this knowledge when solving problems. Creatively is linked with developing their <u>own</u> mathematical knowledge.

3. **Is able to develop and analyse mathematical models for problems from other disciplines and assess their usefulness.**

This has a link with *Solving Problems Creatively,* as it is expected that AM graduates are able to solve problems from other disciplines, which they may have not seen before.

However, this exit qualification also has a link with *Learning new work tasks, technologies and procedures,* because developing mathematical models could be part of their new job requirements.

Next to that, it could also be linked with *Dealing with uncertain and unpredictable work situations.* AM graduates are expected to assess the usefulness of mathematical models, which should be done before taking reasonable actions, as is part of this dimension.

4. **Has a systematic approach, characterized by the application of mathematical theories and development of mathematical methods and models, has a critical attitude.**

This qualification entails the way the AM graduate approaches problems, i.e., about their specific systematic work method. None of the dimensions says anything specific about working systematically. However, the dimension 'Dealing with uncertain and unpredictable work situations' also entails 'imposing structure for self and others that provide as much fixus as possible in dynamic situations […]'. (Pulakos et al., 2000, p. 617) Working systematic is also about creating structure and organising (*Systematic | Meaning in the Cambridge English*

Dictionary, n.d.). So, in this case, this qualification is linked with *Dealing with uncertain and unpredictable situations*.

Next to that, as <u>development</u> of mathematical methods and models is mentioned in the qualification, *Learning new Work Tasks, Technologies and Procedures* is linked indirectly.

5. **Has knowledge and understanding of mathematical and deductive reasoning necessary for and present in rigorous mathematical proofs and is able to apply this kind of reasoning generically.**

This exit qualification is linked with *Solving Problems Creatively.* The programme expects their graduates to be able to have deductive reasoning skills, and to be able to apply this, which comes in handy when solving problems creatively.

6. **Can work in a team and is able to communicate mathematical knowledge verbally and in writing to specialists and non-specialists.**

This is linked with *Demonstrating Interpersonal Adaptability*, because when working in a team and to achieve goals, it is sometimes needed to adjust your personal style.

7. **Is aware of the relation between mathematics and its role in society and is able to integrate this awareness while considering technological and societal problems.**

This exit qualification is linked with one of Meijers et al. (2005) criteria about taking temporal and social context into account. This last qualification could not be linked with one of the dimensions unfortunately.

From this, we expect that the following 4 dimensions are applicable for AM graduates:

Table 7 Four adaptive competencies proposed by Pulakos et al. (2000) most applicable for AM graduates

Dealing with uncertain and unpredictable work situations	This competency involves effectively adjusting work tasks and plans, and taking reasonable action when a new and unfamiliar situation arises.
Learning new tasks, technologies and procedures	Learning work tasks, technologies and procedures involves keeping an eye out on developments related to the job and update skills and knowledge accordingly.
Solving Problems Creatively	This competency involves creating new and innovative solutions to problems, and assess different type of solutions available.
Demonstrating Interpersonal Adaptability	Demonstrating Interpersonal Adaptability means being able to change your own behaviour, goals and opinion in order in order to work well with others. It also encompasses the ability to be open-minded and listen and consider other's opinions and change your own point of view when it's convenient to do so.

4.2.3 Adaptability in the workplace for AM graduates

This thesis is focussed on adaptability in the workplace for AM graduates at the start of their career. Starting a career is seen as something new and unfamiliar. The programme expects their graduates to be competent in the 7 exit qualifications mentioned above and these qualifications are linked with the dimensions proposed by Pulakos et al. (2000). Together, the following definition is developed:

> ***Adaptability in the workplace for AM graduates*** *is the ability to be competent in the following four adaptive competencies proposed by Pulakos et al. (2000): Solving Problems Creatively, Learning new tasks, technologies and procedures, Demonstrating Interpersonal Adaptability, and Dealing with uncertain and unpredictable work situations.*

Exit Qualification AM programme

Adaptive Competencies
(Pulakos et al., 2000)

Adaptability Dimensions
(Charbonnier-Voirin & Roussel, 2013)

Adaptability for AM students in the workplace
(Pulakos et al., 2000)

- Dealing with Uncertain and Unpredictable work Situations
- Learning new Tasks, Technologies and Procedures
- Solving Problems creatively
- Demonstrating Interpersonal Adaptability
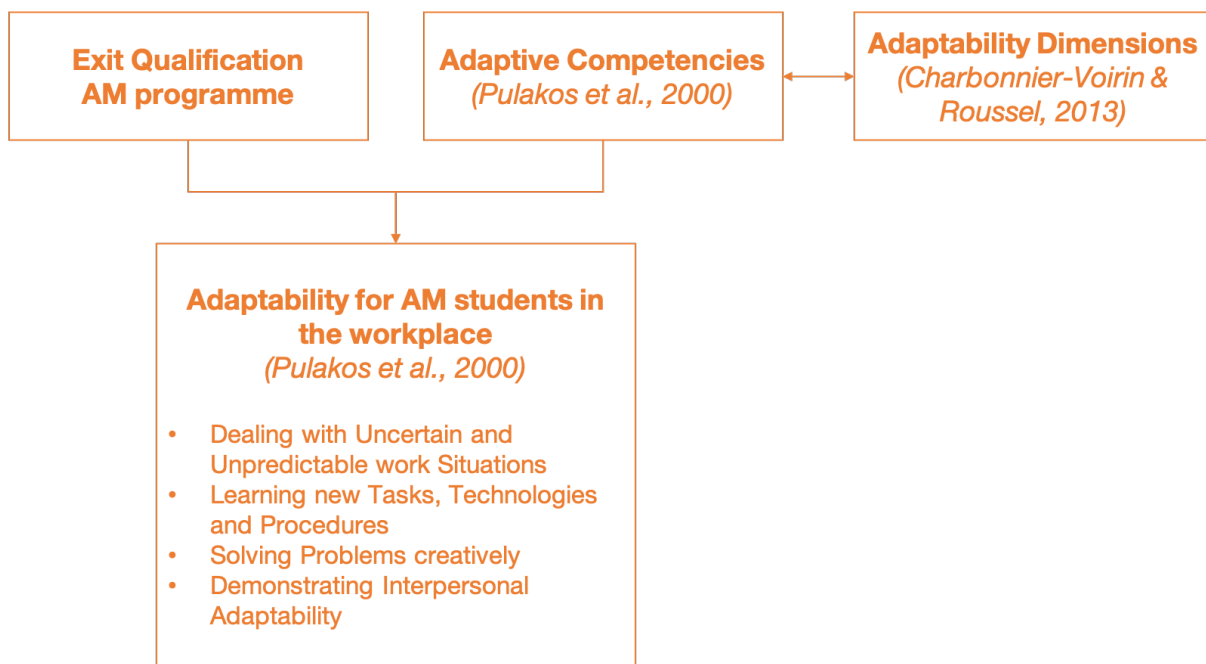
Figure 4 A visual representation of the definition of adaptability for AM students in the workplace

4.3 Chapter Conclusion

This chapter revealed the link between adaptability and the master programme, by connecting the exit qualifications with the adaptive competencies proposed by Pulakos et al. (2000). Four adaptive competencies were found to be most relevant for the graduates, and it is expected that the students have these after graduation.

Next to that, a definition was developed for Adaptability for AM graduates in the workplace.

The next Chapter shows in what kind of situations graduates need to demonstrate adaptability, and what barriers and facilitators are applicable.

5 Barriers & Facilitators AM graduates experience

To answer SQ2, the barriers and facilitators of adaptability at the start of an AM graduates' career will be obtained by means of a survey. In several interviews conducted, some barriers and facilitators were found. Facilitators are items that enable AM graduates to be adaptive, whilst barriers are items that inhibits them to be adaptive. The survey will determine if a large group of graduates' share the same opinion.

5.1 Methodology

To answer SQ2, five alumni were asked to share their experiences at their current job. Four alumni were interviewed for 1 hour each, and one alumnus answered questions in a document. The goal of the interviews was to find out how alumni experienced the start of their professional career and the study programmes preparation for it. These interviews were exploratory interviews, where we asked about their experience to find out what their opinions are on the programme's preparation for their professional career. From these interviews, we found links with several adaptability dimensions, as is described in this section. Next to that, the facilitators and barriers were found by observing the interview transcripts, and by analysing literature.

5.1.1 Sample

In total, five graduates were interviewed, from which 4 students did the master specialization Stochastics, and one student analysis. We choose to keep it at these five interviews, because they all provided information from different sectors, they gained experience in during their internship or at their current job. Of the five graduates interviewed, two graduates currently do a PhD at a university, another graduate does an PhD at a research institution, one graduate works at a bank, and the last graduate at a consultancy company. The graduates also gained experience during their internship: two graduates worked at an ICT, two graduates at a consulting company and one student did her internship at a company focussed on health, which falls under engineering when compared with the companies listed in the Critical Reflection (Lopuhaä, 2019). Lopuhaä mentioned six sectors graduates work in: Finance, Consulting, Engineering, ICT, Science/Research, Other (p. 39). In Other, students pursue a career in education or continue studying. The group sample in this thesis includes interviewees from almost all sectors (none of the interviewees pursued work in education or started another degree).

The alumni graduated between April and November 2019. We choose to interview students who graduated in 2019, because they experienced the gap between programme and labour market recently. So, the graduates still remember what the study programme was like compared to their current job.

Three graduates have a bachelor's in Applied Mathematics at the TU Delft. Two graduates a bachelor's in Applied Physics also at the TU Delft, and both did a bridging programme before they started their master.

5.1.2 Interviews & Coding

The interviews with alumni were semi-structured and were recorded and transcribed. The transcripts were uploaded in Atlas.Ti 8, a programme which allows researchers to analyse qualitative data, such as interview transcripts, documents, etc. The transcripts were read

swiftly to get an overall view what was said in the interviews, after which the transcripts were coded intuitively. The codes were created based on what enables them to perform their job correctly (facilitators), what inhibits them to be perform their job correctly (barriers) and when adaptability was needed. The codes were created by use of open coding, and we used the created codes from other transcripts to code the rest.

Afterwards, the codes were grouped in barriers, facilitators and when adaptability was needed. Within the group, the codes were clustered to find out why they needed to demonstrate adaptability and which of adaptability dimensions were present. However, these codes were not clear enough, so they were analysed again.

In the second try of coding, the transcripts were read again, and codes were added, removed or merged. Instead of investigating what graduates enables or inhibits them to perform their job correctly, we asked ourselves what enables or inhibits them to be adaptive and refer to the adaptive dimensions. The results are presented below.

5.1.3   Literature analysis

Literature was found and read to describe additional barriers and facilitators to add to the list. The article written by Pulakos et al. (2000) was used to find relevant and additional articles about the competencies. These articles described what these competencies were, what is needed to facilitate it, or they described the concept.

5.2   Outcomes

5.2.1   Demonstrating adaptability

When analysing the interview transcript, we found that the graduates described situations where adaptability was needed. These situations were compared with the four adaptability dimensions discovered in Chapter 4. Below, several situations are described together with quotes and codes that shows in what kind of situations or when graduates need to demonstrate adaptability is presented.

Working at a company

Dealing with uncertain and unpredictable work situations
Demonstrating Interpersonal Adaptability

A graduate indicates that their new job also involves politics like the hierarchy when a decision has to be made. Another graduate has to deal with money and privacy factors, which were less or not present in their study programme. Working at a company is also more result-oriented; the company does not care how results are obtained but they are only interested in the result itself. This is also different from what they encountered whilst studying. They have to deal with these unfamiliar work situations.

Next to that, one graduate indicated that she had difficulty adjusting to the political side of the job. The study programme taught her to be transparent and write everything available down (the good and the bad). The managers are not interested in the best way to solve a problem, they just want something that works. However, due to the political side of the job, transparency is not so present at the job as she would have wanted. Therefore, we believe that graduates also have to demonstrate interpersonal adaptability, i.e., whenever she

communicates with the manager or supervisor, she has to change her need to be transparent in every situation.

Table 8 Quotes and codes related to 'working at a company'

Codes	Quotes
The industry also has a political side	"It's more convenient not to put everything on the table. You have to play politics in business." (A3)[9] "Don't lie, but don't say the right things" (A3)
Money and privacy factors are new	"Amongst other things, money and time are the biggest component, but also the legal feasibility (privacy)" (A2)
Working in the industry is about money	"Amongst other things, money and time are the biggest component, but also the legal feasibility (privacy)" (A2)
Working in the industry is result-oriented	"They just don't care how you get it as long as you get results. In itself, I understand that you're more attached to time, who cares how it works. If you're the fastest and can earn the most". (A4)

Different work method at a company

Learning new work tasks, technologies and procedures

During their job or internship, graduates encountered new aspects for which they had to learn new tasks, technologies or procedures, e.g., they have to keep the work of high quality, which is a challenge; the time pressure is way different, because at their master the planning was already laid out for them. Next to that, as told before, they also do not have to tell everything they find out and in addition, they have to sell their work. A graduate explained that the solutions she found are not the best, but still, she has to sell these results and does not have to explain everything she knows, only the good stuff.

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[9] A3 refers to Alumni 3, one of the 5 alumni interviewed.

Codes	Quotes
Keeping high quality is a challenge	"To keep it high quality is always the challenge".
Time pressure at work is complicated	"You can still be as stuck on a problem as you are on a math problem, but often the time pressure makes it much more complicated".
Don't write down everything you know	"I think the difference comes from the fact that at university everything must be true. So, you only write down what is true. I really had to unlearn that in business. I also write down everything that's not true, because everything is valuable in a university. But in business you have to write more cleverly, so you have to write down everything that is right, the rest you have to call a bit like half, not mention it. Just like you have to sell your work." "Don't lie, but don't say the right things" "The transparency" (on the question what are their biggest challenges are right now during your work)
Selling the work that's done	"I think the difference comes from the fact that at university everything must be true. So, you only write down what is true. I really had to unlearn that in business. I also write down everything that's not true, because everything is valuable in a university. But in business you have to write more cleverly, so you have to write down everything that is right, the rest you have to call a bit like half, not mention it. Just like you have to sell your work." "you should try to sell your own model, look this is the data this is good. Do you know the sales behaviour, selling your work if you know it's not as good as you would like". "The transparency" (on the question what are your biggest challenges right now during your work)

Communication and Collaboration

Demonstrating Interpersonal Adaptability

Working at a company is different, because the graduates have to communicate with different people. At the study programme, they mostly work with students like themselves, but at work, they have to work with people from all different backgrounds or personalities. Therefore, they have to listen to others, and change their behaviour to collaborate and develop relationships with them, i.e., they have to demonstrate interpersonal adaptability.

Codes	Quotes
Communicating with others	"communication with people who are different from you. [different or different background] not even different background, just make different personality" (A3) "I find that difficult and that communication with that annoying colleague"
Not used to collaboration	"that working together might be a thing. You're not really used to that." (A4)
Difference in knowledge with colleagues	"but I do notice that my colleagues don't always, they don't have a technical background" (A3) "but then you still have to explain it to managers who have done economics or business, who have no math background at all and you're going to simplify so much that at least the model is a little explainable, then everyone knows a little bit what it's about". (A3)
The job requires multidisciplinary collaboration	"Because you have to work together with people I work with now, who don't understand math, but also have their own way of writing documents". (A3) "but I do notice that my colleagues don't always, they don't have a technical background" (A3) "but then you still have to explain it to managers who have done economics or business, who have no math background at all and you're going to simplify so much that at least the model is a little explainable, then everyone knows a little bit what it's about". (A3) "With someone who did astronomy, someone who did econometrics. My colleagues are all physicists or econometricians." (A3) "of working with people who didn't do math." (A3)

Working with projects

Dealing with uncertain and unpredictable work situations

A graduate explained that the project they have to work on during the master are almost always perfect, while at their job or internship they are not. Next to that, another graduate also explains that at the company he worked at, he also has to deal with added unexpected information a day before the deadline, which he has to deal with or solve. Both graduates thus have to deal with uncertain and unpredictable work situations.

Table 11 Quotes and codes related to 'working with projects'

Codes	Quotes
Sudden changes	"At work, it's okay for something else to happen half a day before a deadline, which leads to new insights and requires more research." (A2)
Projects are not perfect	"that was the first course where you got such a big assignment that it would look like something serious. And for the rest, you get those tor examples, which are actually too well put together, so you do not run into anything. And of course, it's not like that] no it's never that beautiful". (A4)

PhD – 'there is always more'

Solving Problems Creatively

Two graduates we interviewed were PhD students and they both explain that there is always more mathematical information to investigate and there is no answer yet for a lot of questions. Because there is always more, they have to assess several possible solution paths and take reasonable action. Next to that, no exact solution involves thinking outside the box and find effective solution approaches. Therefore, they have to solve problems creatively.

Table 12 Quotes and codes related to 'PhD - there is always more'

Codes	Quotes
There is always more mathematics	"so yes, you have solved the whole problem, then there are other questions of go on. There is always more."
There is no answer	"the problems you're working on or the questions you're asking, you don't know if there's an answer to them. And that is difficult" "there was already an answer there is someone who knew the answer who can guide you there and now there is not. Also, my supervisor doesn't know how things are done".

Mathematics is a tool not the goal

*Dealing with uncertain and unpredictable work situations &
Demonstrating interpersonal Adaptability*

Graduates indicate that companies are satisfied with simple models, because these models are easier to understand for managerial people who do not necessarily work with or understand the models, but have to make decisions on which model to use. So, the graduates cannot add more mathematics in the models. Because graduates are used to work with difficult models, they have to deal with these new work situations, e.g., working on simpler models, and have to change their behaviour accordingly.

Table 13 Quotes and codes related to 'mathematics is a tool not the goal'

Codes	Quotes
Simpler models are sufficient	"That companies often settle for much simpler models than is possible" (A2) "but then you still have to explain it to managers who have done economics or business, who have no math background at all and you're going to simplify so much that at least the model is a little explainable, then everyone knows a little bit what it's about". (A3) "They didn't care at all how such a [method] worked. I had that data so I just had to clean it up and then come in in the right order and that [method] would just give an answer. At one point I got the right one with 70% and then they were over the moon. And I was not very pleased with it. I had made it in python and I really had no idea why it worked." (A4)
Can't add more mathematics	"Because I can do more and you run into the fact that a mathematician can build a very difficult model, but then you still have to explain it to managers who have done economics or business, who don't have a math background at all and you're going to simplify it so much that at least the model will be a little explainable, then everyone will know a little bit about it". (A3)

Being critical

Demonstrating Interpersonal Adaptability

One student said that he would like to be more critical and ask more critical questions as it could help him perform his job better. At the moment his supervisor asks the critical questions, but in the future, he would like to have this skill.

In order to do his job better, he has to change his behaviour. He now listens to his supervisor to learn from him.

Table 14 Quotes and codes related to 'being critical'

Codes	Quotes
Asking critical questions	"skills that I still have to develop, or I hope that after those four years I will be able to ask those questions myself. Now I am solving a question from one of my supervisors and then yes this is it and then maybe I have a small question. But they can ask such questions there is a whole world opening up, asking good questions that is quite an experience. I think that will come with time". (A4)

In the next subsection, we present the facilitators and barriers found in the interviews we conducted with graduates. In subsection 5.3, all the facilitators and barriers found in the interviews are presented.

5.2.2   Facilitators

Facilitators are the items that enables graduates to be adaptive. The graduates mentioned items that enables them to perform their job better, which could be linked to one of the four dimensions. We found the following items:

Doing projects where one has to work together

This facilitator entails doing a collaborative project with others, such as students from a different field or for a company. Next to that, a bachelor's thesis is also a project.

Graduates indicate that several courses or projects they worked on during their master were useful as the experience helps them do their job now. Examples are: a graduate explained that her BEP taught her how to handle a project, two graduates said that the practical project they worked on with students from another field, was also useful as it taught them to work with people from different background, and others said that a course they followed during their master programme where they had to do a project for a company was fun and useful.

These are skills and knowledge (handling projects, know how to work with students from different backgrounds or for a company) they learned from the programme which helped them do their job now. They had to *Demonstrate Interpersonal Adaptability* (doing a project with students from another study programme), but they also had to deal with *Uncertain and Unpredictable Work Tasks, Technologies or Procedures* and *Solve Problems Creatively* (working on a project for a company, which they have not done before; the thesis involves solving problems uniquely).

Receiving help from others

Receiving help entails getting help from others, such as colleagues, supervisors, coaches, etc.

The graduates almost all say that when they encounter an *uncertain or unpredictable situation*, e.g., a sudden change in the project, not knowing how to proceed a problem, or not knowing how to deal with a colleague, they get help from others: their colleagues, coaches, supervisors, managers.

Doing training

This facilitator entails getting extra training or follow extra courses to perform the job better.

Next to that, they also have the opportunity to follow training or courses to deal with that or to *learn new work tasks, technologies or procedures*.

Networking

Networking is looking for collaboration partners who you could contact when you want to work together, or need help.

One graduate said that networking is important as it enables him to contact relevant people to work together on projects. He said it's needed to have a connection as it makes it easier to find help. This is linked with *Dealing With Uncertain and Unpredictable Situations* as his connections could help him deal when this happens.

Next to that, it's also linked with *Learning New Work Tasks, Technologies and Procedures*, as he believes learning to network is needed to perform his job better

5.2.3 Barriers

Barriers are the items that inhibits the graduate to be adaptive. This was more difficult to find in the interviews, as students did not really mention what limits them to do their job which also could be linked to adaptability. We found the following

Negative corporate culture

The facilitator corporate culture entails the surrounding at the job, i.e., chatting with colleagues.

A graduate indicated that he did not like the corporate culture, and that he missed chatting with colleagues. He also said that he would keep that in mind when he looks for a future job. As he missed chatting, he did not *Demonstrate* a lot of *Interpersonal Adaptability* as he did not communicate with his colleagues much.

Not asking questions

This entails not having the right to ask questions or ask for help during the job.

A graduate followed her internship at a consultancy company, where people worked on project base. As they work and receive money per project, she did not want to ask questions, because her colleagues would spend less time on the project, which indirectly links to losing money. Because of this, she was not able to *Solve Problems Creatively*, as she did not receive a lot of help from colleagues.

Next to that, she was also not fully able to *Deal with Uncertain and Unpredictable Situations* as she could not ask all the questions to solve the uncertain situation she encountered.

Not using all the mathematical skills and knowledge

This facilitator is about not using all the mathematical skills and knowledge one possesses.

Almost all students say that the mathematics they use in a company is less than what they expected. As the graduates know a lot, they could also do more when working on a project and go further into the mathematical details. However, due to the company they are working for not wanting to go deeper, they are not able to *Solve Problems Creatively* as much as they are used to, as they are not using their full set of skills.

Not being transparent

With transparency, we mean not being able to say everything you know about a certain topic. Working in the industry is political, and does not require fully transparency in some cases.

As the corporate world is political, a graduate said that she does not have to explain every step or thing she encountered, only to good things, as was told previously. She should not be as transparent as she is used to, and for this reason, it is difficult for her to *Solve Problems Creatively,* as she has to be less transparent which she is not used to.

5.2.4   Additional Barriers and Facilitators from literature

Note that, all these barriers and facilitators were not obtained by asking the interviewees what inhibits them to be adaptive or what enables them, but by analysing their interview transcripts about how they experienced the start of their career. Next to that, these barriers & facilitators were linked to Pulakos et al.'s dimensions by the author of this thesis and not with the help of research.

So, to find additional barriers & facilitators, we have dived deeper in the literature of the dimensions and found some more which is presented below.

5.2.4.1   *Dealing with uncertain and unpredictable work situations*

Ashford & Dartmouth (1986) investigated feedback-seeking in organizations, where they focus on individuals seeking feedback "on important issues and in new and uncertain situations" (p. 465). They say that adapting to fit the demands of a specific environment is based on provided or obtained information about that environment. Feedback is useful as individuals know whether their changed and new behaviour fits the environment and its goals. Ashford & Dartmouth (1986) define uncertainty as "a state in which individuals have no little, or inconsistent information about the stimuli of interest." (p. 468) In an uncertain environment, individuals perceived value of feedback should increase, because such information helps them structure the situation and make decisions on how to go further.

Griffin et al. (2007) wrote an article about work role performance, and proposed that valued behaviours in organizations are shaped and constrained by work context. They described that in order for organizations to be effective, they have to handle uncertainty and interdependence as two features of context. They use three levels at "which role behaviours can contribute to effectiveness (individual, team, and organization) and the three different forms of behaviour (proficiency, adaptivity, and proactivity) into subdimensions of work role

performance." (p. 330) Individual adaptivity is linked with 'dealing with uncertain work situations', and Team adaptivity with 'interpersonal adaptability'.

Below, we summarized items that facilitates or inhibits dealing with uncertain situations.

Receiving Feedback

With feedback we mean receiving information from others in new and uncertain environments.

Ashford & Dartmouth (1986) propose that *feedback* is valuable for everyone entering a new environment, such as a new company. "Feedback helps individuals both to understand new environments and to map their evaluative contingencies, thereby enabling successful adaption." (p. 589) So, it helps individuals to cope with uncertain and unpredictable work situations (Ashford, 1986)

Being Open to Change

Openness to Change means being able to change and respond flexible when one enters a new and uncertain environment.

Griffin et al. (2007) discovered that *Openness to Change* is a predictor of Individual, Team and Organizational adaptivity. They "expected that individuals who were more open to change would feel more positive about change in their organizational context and would be motivated to respond [flexible] when confronted by change." (p. 334) So, from this, we conclude that whenever an individual is open to change, he/she will display a form of adaptivity, i.e., individual and team. These forms are linked with dealing with uncertain and unpredictable work situations, and Interpersonal Adaptability. (p. 329)

Both *Feedback* and *Open to Change* are added to the list of facilitators.

Table 15 Barriers and Facilitators of Dealing with Uncertain and Unpredictable Work Situations found in literature

Facilitators (2)	Barriers (0)
Receiving Feedback	-
Being Open to Change	

5.2.4.2 Learning new work tasks, technologies and procedures

Boud & Middleton (2003) investigated learning from others at work, by examining who is involved in informal learning, and how learning takes place. Next to that, they also considered informal learning in communities of practice (CoP), and whether a CoP is helpful when considering learning from others. CoP helps create identity and meaning.

They found, among others, that the employees responsible for learning at the workplace, such as supervisors or trainers, are not mostly used as learning opportunities by other employees. Next to that, "the range and diversity of communities of practice in which one may legitimately participate increases with seniority, and therefore the range of opportunities for informal learning increases as do the types of learning." (Boud & Middleton, 2003, p. 202)

From this, we may conclude that employees firstly ask their direct colleague for help or feedback than their supervisors or trainers. So, *learn from direct colleagues* is added to the list of facilitators.

Tynjälä (2008) investigated past research on workplace learning, and divided the article in two sections: firstly, he questioned what is known about learning at work and stated four propositions, secondly, he considered workplace learning related to formal education. Tynjälä explains that people learn in different ways, where he lists six ways of learning on the job, which ranges from 'doing the job itself' to 'tackling challenging and new tasks'. Next to that, he also lists seven categories of learning outcomes, ranging from 'task performance' to 'personal development'.

Networking

Networking means using one's social network to learn more and to create knowledge.

Tynjälä (2008) mentions "the importance of networking and other forms of social exchange for both individual learning and organisational development." (p. 136). Networking was also mentioned by one of the graduates as an important skill to have. Tynjälä explains that people form social networks in their work to create knowledge, where he also defines learning as a "knowledge creation process that takes place in social interaction […]." (p. 136) From this, one may conclude that *networking* could be seen as a facilitator of *Learning new Work Tasks, Technologies and Procedures*, as networking enhances learning.

Participate in formal learning

Tynjälä (2008) suggests that for organizations to be successful, they should develop a way to utilize formal school learning, because informal learning is unintentional and yields only tacit knowledge. New technologies emerge every day, which is difficult to keep up with it. Formal learning could make informal learning more effectively. For this reason, as individuals participate in formal learning opportunities at work, such as trainings and lectures, the individuals will learn more effectively. For this reason, '*participate in formal learning*' is added as a facilitator.

Having Freedom

Freedom means having a job with a broad description, new tasks, and non-controlled procedures.

Tynjälä mentions "that workers with narrow job descriptions, repetitive tasks, controlled procedures and little opportunities for autonomous decision making, […] [have fewer] opportunities for learning and development." (2008, p. 141) On the other end, "when workers are rotated between jobs, tasks are carried out by collaborative and self-managed teams with a lot of autonomy, and workers are encouraged to share their expertise and develop their work." (2008, p. 141) In this case, new challenges and learning opportunities are provided by work. So, we added '*Having Freedom*' and '*Not Having Freedom*' as a facilitator and barrier respectively.

Participate in trainings

Participate in trainings means participating in formal learning opportunities.

Another important aspect is that not only the context and conditions of learning determines learning, the reciprocal interaction between individuals and the workplace also plays a role: "the nature of individuals' participation in workplace learning depends both on the extent to which the workplace provides opportunities for such participation and on the extent to which individuals choose to avail themselves of those opportunities." (Tynjälä, 2008, p. 141) From this one may conclude that when the workplace provides opportunities for participation, and the individual chooses to use these, then learning takes place. Whenever this is not the case, learning takes less place. So, from this we added '*participating in trainings'* to the list of facilitators, and the negation of it is added to the list of barriers.

Participating in work situations

Participate in work situations means participating in the normal work situations one encounters.

Collaborate with others

With this we mean, working together with others.

Do New Challenges

This item entails doing new challenges.

Tynjälä explains that learning at work takes place when employees participate in work situations, collaborate with colleagues, clients and do new challenges. (2008, p. 150) From this, we conclude that employees learn new task, technologies or procedures by *participating in work situations*, *collaborate with others* and *do new challenges*. These items are added to the list of facilitators.

Collaborate with others is linked with *learn from direct colleagues*, as while collaborating with others, i.e., your colleagues, you learn from them. So, we combined these two to '*Collaborate with and learn from colleagues.*'

Table 16 Barriers and Facilitators of Learning new Work Tasks, Technologies and Procedures found in literature

Facilitator (7)	Barrier (1)
Having Freedom	Not having freedom
Networking	
Participate in formal learning	
Participate in trainings	
Participate in work situations	
Collaborate with and learn from others	
Do new Challenges	

5.2.4.3 Solving Problems Creatively

Mumford et al. (1997) investigated how organizations influence creative problem solving among their employees, and how employees' creative problem solving (CPS) attempts are positively or negatively influenced by several facets of their work. Next to that, they also considered how novel ill-defined problems are solved, because creative problem solving occurs when employees have to solve novel, ill-defined problems. At the end of the article, they present actions organizations could take that could encourage creative thought among their employees. In another article by Mumford et al. (2018), they examined why creative problem-solving fails. At the end, they discuss how others could help people become more successful in their creative problem-solving attempts. They limit themselves to three areas of failure: (1) nature of the problem, (2) problem-solving capacities, and (3) context of problem solving. They conclude with a list of reasons why creative problem-solving fails (p. 390).

Below, we list a couple of their recommendations or reasons as items that enables creative problem solving, which are applicable for the AM graduates:

Having Freedom

Having freedom entails having non-stable jobs and having job tasks which are not fixed.

Mumford et al. (1997) explain that people who have stable jobs, i.e., their job tasks are fixed and they do not have a lot of freedom, have less opportunities for creative problem solving. They also say that when individuals are allowed to choose what to work on with more flexible deadlines, they produce more creative designs.

Having a lot of tasks

This means having a lot of tasks, which consumes all the available time and effort a person has.

Stress inhibits creative thought (Mumford et al., 1997), so they say that organizations should decrease overload of work to increase creative problem solving.

Not necessary to generate creative solutions

With this we mean it's not necessary to generate creative solutions, i.e., the managers settle for the easiest and quickest solution.

Decision makers, like managers, settle for the first solution which solves the problem immediately, instead of motivating employees to generate better alternatives. The employees are not encouraged for creative problem solving, because it's not necessary to do so. One of the graduates also said that the company where he did his internship, was happy with all he submitted, but he felt like he could have done more.

Having the right resources

This means having the right resources, such as technology and equipment, available to do the job.

The available resources, e.g., technologies or other things that enhance creative thought, also influence creative problem solving. They say that promoting "creative problem-solving is to provide requisite resources." (Mumford et al., 1997, p. 12) In their article, they give an example about a scientist who does not have the right equipment, and about fiscal resources. However, in line with this research, resource is the right equipment, which could be technology or hands-on equipment or help from others, like colleagues and supervisors.

Mumford et al. (2018) mentioned that specific professions are skilled in specific tasks, and not investing in resources that enhance these tasks, will limit creative thought. Just like above, with resources we mean, technology, hands-on equipment or help from others, like colleagues and supervisors.

Recognize when a problem calls for creative thought

Do not recognize means not being able to recognize when a problem calls for creative problem solving.

Mumford et al. (2018) said "Failure to construe a problem as a problem calling for creative thinking clearly will lead to failure in any creative problem-solving effort." (p. 379) Whenever someone recognizes that the problem requires creative thought, one should also see that the problem also requires originality, and if not, that it will lead to failure in their creative problem-solving attempts. Mumford et al. also mentioned that "the production of viable problem definitions results in creative problem solutions of higher quality, originality, and elegance." (2018, p. 380)

Not knowing how to solve problems creatively

With this we mean when people do not know when to use their creative problem-solving skills.

Two of the proposed reasons imply that whenever people do not know how to tackle an undefined, complex problem, they are not able to use their creative thought, which negatively influences their creative problem-solving efforts.

Being able to self-reflect

With this item, we mean that whenever a person is able to handle criticism, and foresee potential errors.

The last item they point out has something to do with self-reflection. Mumford et al. (2018) mentioned that "creative people use criticisms, or awareness of potential errors, in formulating viable problem solutions." (p. 383) So, whenever an individual is not able to recognize and foresee errors, or does not use criticism as a resource, their creative problem-solving attempts may fail.

From this, we found the following barriers and facilitators of Solving Problems Creatively

Table 17 Barriers and Facilitators of Solving Problems Creatively found in literature

Facilitators (4)	Barriers (6)
Having Freedom	Not having Freedom
Having the right resources	Not having the right resources
Recognize when a problem calls for creative thought	Not recognize when a problem calls for creative thought
Being able to self-reflect	-
-	Not necessary to generate creative solutions
	Not being able to see what could be done differently
	Having a lot of tasks

5.2.4.4 Demonstrating Interpersonal Adaptability

Oliver & Lievens (2014) define interpersonal adaptability as "the fit of an individual's interpersonal behaviour, thoughts, and emotions within an interpersonal interaction in order to achieve the goals afforded by the situational demands of the interaction" (p. 5), for which the definition highlights the following 5 aspects:

1. "Interpersonal adaptability is a **functional construct**" (p. 5), i.e., it's context dependent.
2. "Interpersonal adaptability is **multidimensional"** (p. 5), i.e., it depends on "interpersonal skills & interpersonal processes, such as perception and appraisal, and strategy selection" (p. 6)
3. "Interpersonal adaptability occurs within an **interpersonal interaction**." (p. 5) "In every interpersonal interaction, an individual is continually required to monitor the actions of others and adjust his or her own actions, thoughts, and emotions in order to effectively attempt to reach his or her goal(s) for the interaction." (p. 6)

4. "Situational demands can be conceptualized by the **goals** that they afford." (p. 5) "Individuals draw upon the demands of a situation to select goals, select and adjust strategies to achieve their goals, and monitor goal attainment." (p. 7)
5. "Interpersonal adaptability is a **measure of fit**." (p. 5) "The concept of fit implies that skills that are effective for one set of situational demands will not necessarily be effective for another set of situational demands." (p. 7)

From these aspects the following three items are developed.

(Not) Knowing when to demonstrate

With situations we mean when people demonstrate types of interpersonal adaptability. Each situation requires different level of interpersonal adaptability.

Interpersonal adaptability is context dependent, so not in every situation is interpersonal adaptability or the same level of it required, e.g., coping or reacting to a stressful situation is different from working on a task that's altered. (Oliver & Lievens, 2014) As Oliver & Lievens mention that stressful situations, altered environments, new work tasks, or when individuals "proactively initiating change to a stable environment" (p. 6) require different levels of interpersonal adaptability, one could say that either of these options may be barriers or facilitators. However, we do not know if these items either inhibit or enable adaptability. For this reason, we created the barrier & facilitator 'situation'. So, as a barrier: *'I do not know when to demonstrate interpersonal adaptability'*, and as a facilitator: *'I know when to demonstrate interpersonal adaptability',* with when implying a specific situation.

Participate in social work situations

Colleagues or employees demonstrate (different types of) interpersonal adaptability when they participate in social work situations together.

Oliver & Lievens imply that in order to demonstrate interpersonal adaptability, individuals should participate in social (work) situations with their colleagues. So, *(not) participate in social work situations* is added to both the list of barriers and facilitators.

(Not) Knowing which skills to employ in order to demonstrate interpersonal adaptability

With measure of fit, we mean what skills are needed to fit the demands of a situation.

Item 5 says something about what a person should do in order to fit to the demands of the situation. For example, coping or reacting to a stressful situation requires different skills than is needed when working on an altered task. So, we added *measure of fit* to both lists: as a barrier *'I do not know which skills I could employ in order to meet the demands of the situation'*, and as a facilitator *'I know which skills are needed to fit to the demands of the situation.'*

In this thesis, interpersonal adaptability is mainly focused on collaborating with others, and about an individual being able to adapt oneself to fit the demands of the situation. Item two is more about the interpersonal skills and procedures of an individual, while the other elements from which we developed barriers/facilitators, are more about the situation itself and participating in it, as we also mentioned in our definition of interpersonal adaptability.

Item four says something about the goals of the situation, as each individual has goals whenever the individual participates in social situations. However, these goals are different for each situation. As we already mention situations as a barrier/facilitator, item four is therefore used.

Table 18 Barriers and Facilitators of Demonstrating Interpersonal Adaptability found in literature

Facilitators (3)	Barriers (3)
Knowing when to demonstrate	Not knowing when to demonstrate
Participate in social work situations	Not participating in social work situations
Knowing which skills to employ in order to demonstrate interpersonal adaptability	Not knowing which skills to employ in order to demonstrate interpersonal adaptability

5.3 Chapter Conclusion

This chapter presented the barriers and facilitators AM graduates encounter to adapt to situations in their job. Chapter 3 and 4 examined adaptability in the workplace and presented a theoretical framework. A definition of adaptability for AM graduates in the workplace is developed and used to determine what kind of situations they encounter in which adaptability is needed as well as the barriers and facilitators from the interviews. Additional barriers and facilitators are identified from literature. With this, SQ2 could be answered partially, because we would like to know if more graduates believe these barriers and facilitators are indeed barriers and facilitators and if the ones we found from literature apply for these students. The whole answer was obtained with the results of the survey.

What barriers and facilitators do AM graduates encounter to adapt to activities in their job?

The partial answer is presented in Table 19:

Table 19 Barriers & Facilitators graduates encountered at their current job found in interviews

	Found in interviews	Dealing with uncertain and unpredictable work situations	Learning work tasks, technologies and procedures	Solving Problems Creatively	Demonstrating Interpersonal Adaptability
Facilitators	**Doing Projects**		O	O	O
	Receiving Help	O	O		
	Networking	O	O		
	Training		O		
Barriers	**Corporate culture**				O
	Not being able to ask questions	O		O	
	Not using all their deep mathematical knowledge			O	
	Transparency			O	

The barriers and facilitators found in literature are not yet part of the answer to SQ2, because these ones are found in literature and are not yet acknowledged by the graduates. The survey determined which of the 'literature found' barriers and facilitators are recognized by the graduates.

6   Survey

In the beginning of October, a survey was sent out to find out whether students have these adaptive competencies and to obtain barriers and facilitators of the perceived adaptive competencies. The barriers and facilitators from the previous chapter served as a guideline for the development of this survey, as well as the adaptive competencies mentioned in Chapter 4.

The survey is divided into five categories: Introduction, Adaptability, Education, Internship, and Current Job. In the introduction, participants received information about this thesis as well as the privacy regulations, after which they could choose to participate or not. In the Methodology of this Chapter, we described the other four categories in more detail.

6.1   Methodology

6.1.1   Survey Development

6.1.1.1   Analysis software

The survey was developed with the use of Qualtrics, an online questionnaire programme. A survey was used to determine if graduates of the AM programme are adaptive or not, and which barriers and facilitators they find important, and which of these are much more popular over others, which is not possible when conducting interviews, because it would have involved time constraints.

After the data was obtained, SPSS, a statistical software programme, was used to analyse the results. Mostly descriptive analysis was used, but the standard deviation and averages were also calculated. Overall, SPSS was used to determine how adaptive students were, which barriers and facilitators were most applicable for the students, but also about their current job, education and how satisfied they were with the internship, master thesis, and the programme in general.

Participants had to rate a combination of statements on a 4-point Likert-scale to determine if the students had the related adaptive competency. The students could choose between 'I strongly disagree' to 'I strongly agree', with the mid-option (neutral option) omitted to force a side. The option 'I strongly disagree' was one and 'I strongly agree' was a five. With the choices per statement an average was calculated in which all the numbers related to the options were added and divided by the number of statements. If the student had an average below or equal to three, the participant was perceived as 'not adaptive', and above one the participant was perceived as 'adaptive'. The averages was used to calculate the overall average, and the standard deviation in SPSS.

Graduates who were adaptive got different questions than the students who were not adaptive, to obtain the barriers and facilitators. Tables were made in SPSS that presented how many times a barrier or facilitator was chosen. Next to that, participants could also enter their own option.

Graduates also had to rate a couple of statements on a six-point Likert-scale related to their internship and master thesis. Students could choose between 'strongly disagree' on the one side, which was a one in SPSS, and 'strongly agree', on the other side which was a five. Here,

the neutral option was an option. The option 'I cannot remember / not applicable' was added, which was processed as missing data in SPSS.

Next to a fixed set of option participants could choose from, the graduates were also allowed to enter additional answers in the barriers & facilitators section or in the education and current job section.

In the next subsection, we explained the statements, and questions related to adaptability in more detail.

6.1.1.2 Adaptability

At the beginning of the survey, a small introduction to the concept Adaptability as well as a definition were presented. In the first section of the survey called 'Adaptability', the graduates had to rate statements related to their experience at their current job which links to one of the adaptive dimensions, which yielded if graduates have the adaptive competencies. These statements cover the meaning of the competencies, and are based on the definition by Pulakos et al. (2000). We also used statements written by Charbonnier-Voirin & Rousell (2012). Together, we developed a couple of statements, which is presented in Table 20. Appendix E. presents the operationalization table used to develop the survey.

If a graduate is (not fully) adaptive (yet), the graduate received the following questions:

When not fully adaptive	*Based on your answers, you might not be fully able to deal with uncertain and unpredictable situations.*
	What do you think the reason for this is? (Barrier)
	What do you need to increase or do differently in order to improve this competency? (Possible solution direction)
When adaptive	*Based on your answers, you are able to deal with uncertain and unpredictable situations.*
	What do you think the reason for this is? (Facilitator)

When the graduate is not fully adaptive, the answers to the questions are the barriers of the adaptive competency. The non-adaptive students were also asked what they need to increase or do differently in order to improve this competency. The reason for this question was to find a possible solution direction to develop the tool for. When the graduate is adaptive, the answer to the question obtains the facilitators.

The set of choices are different per adaptive competency as not all the barriers or facilitators are applicable for each competency. Table 19 and Table 36 present the barriers and facilitators from interviews and literature respectively per adaptive competence.

The adaptive and non-adaptive students were both asked if the master programme is responsible to teach them these competencies. The adaptive students also got the question if the programme taught them these competencies.

Adaptive competency	Statements
Dealing with uncertain and unpredictable work situations	I am able to work in a changing environment
	I am able to adapt myself when the environment changes
	I perceive change as a nice way to challenge myself
	I am able to develop multiple solutions for a problem
	I am able to assess multiple solutions for a problem
	I am able to take reasonable action to solve a problem
	I remain calm when faced with new and unfamiliar situations
	I am able to easily adapt my work when the environment changes
Learning work tasks, technologies and procedures	I am able to learn to do new tasks to perform my job better
	I am able to work with new technologies that are needed to fulfil my job
	I improve myself to perform better in the work field
	I anticipate future job needs to perform my job better
	I prepare myself for future job needs
Solving Problems Creatively	I am able to solve problems for which there are no clear answers yet
	I am able to develop unusual and creative solutions to unfamiliar problems
	I enjoy working on unfamiliar problems
	I perceive unfamiliar problems as a nice way to challenge myself
Demonstrating Interpersonal Adaptability	I adjust myself to work effectively with co-workers or in a team
	I am able to anticipate my co-workers, clients or managers needs
	I am able to fulfil my co-workers, clients or managers needs
	I take an active attitude to better collaborate with my colleagues
	My colleagues help me perform my job better

6.1.1.3 Education

Graduates had to answer questions related to their education: which bachelor's degree they have and where they obtained it, next to the specialization they did. The results are presented in Appendix G3.

6.1.1.4 Internship & Master Thesis

Participants had to rate statements about the preparation offered by the programme for the internship they did as part of their non-mathematical electives and/or as part of their master thesis. The alumni had to rate these statements on a five-point Likert-scale that went from strongly disagree to strongly agree. Here the option 'I cannot remember / not applicable'. Strongly disagree is 1 and strongly agree 5. When participants choose 'I cannot remember / not applicable' the data was treated as lost data in SPSS.

The participants also rated statements on how satisfied they were with their internship, and if the internship prepared them for their professional career.

Students who did an internship as part of their electives received other different statements than from the students who did an internship for their master thesis. Appendix G5 presents the statements as well as the results.

6.1.1.5 Current job

The alumni answered questions about their current job. Firstly, they were asked to choose what kind of job they do at the moment: research, applied, teaching, or other, for which they could submit an answer. Secondly, we asked them in which month and year they started working. Thirdly, they were asked to choose what kind of tasks they do at their job. Fourthly, the participants had to rate statements on how much mathematics they use and apply at their job, on a five-point Likert-scale from strongly disagree to strongly agree. Finally, they had to choose what kind of tasks they would like to do in the future.

The results are presented in Appendix G4.

6.1.2 Sample

In total 40 participants started the survey, from which 7 did not start, and 9 partially filled in the survey. The survey was sent out to alumni who graduated between June 2017 and the day it was send out in 2020. These participants thus have at the most 3 years' work experience, but are still starters which means they might be still settling to the workplace.

Data from participants who decided to quit before completing it was still useful to analyse, and we kept as many data as possible. From the 33 participants, 14 students did a bachelor's in Applied Mathematics at the TU Delft, 2 students did a bachelor's in Applied Physics, 2 students did a double bachelor programme Applied Mathematics and Applied Physics, and 6 students did different bachelor programmes. Three students have an international bachelor's degree.

In total, 10 participants do a research type of job, 10 a job which is more on the applied side, and 2 are teachers. Two students added two other options: leading and analysing data. It is true that leading is not part of research, applied and teaching as it could be part of all. The same holds for analysing data as it could also be part of research and applied.

Appendix G3 presents the month and year the participants graduated.

6.2 Outcomes

6.2.1 Survey Results

On the 1st of October 2020, the survey was sent out to alumni[10]. The survey was also sent to alumni via LinkedIn. In total, 40 people started the survey, from which 24 completed it, nine partially filled in the survey and seven only agreed with starting the survey but did not continue.

Almost all participants have these perceived competencies, which means that a small number of participants did not have these perceived competencies. As there were so little results with an average below or equal to three, the next subsections only describe the results with an average above three. Appendix G2 presents additional results and the results with an average below or equal to three per adaptive competency.

Firstly, Dealing with uncertain and unpredictable work situations is described, after which the results of the other three competencies are presented.

6.2.1.1 Dealing with uncertain and unpredictable work situations

This competency involves effectively adjusting work tasks and plans, and taking reasonable action when a new and unfamiliar situation arises.

The participants had to rate eight statements, for which an average per participant is calculated. Table 21 presents the mean and standard deviation of all the averages per participant for Dealing with Uncertain and Unpredictable Work Situations. The table also presents the min, max, the number of participants, the number of responses who had an average below or equal to three, or above three.

Table 21 Mean, min, max and standard deviation for Dealing with uncertain and unpredictable work situations

	Mean	Min	Max	Standard deviation	N	=<3	>3
Dealing with Uncertain and unpredictable work situations	4.1932	2.88	5	0.46466	33	1	32

As seen in the table above, the mean is above average, so most participants believe they have this perceived competency. Of the 33 responses, only one scored below three.

When asked if dealing with unpredictable work situations is part of their current job, 23 out of 33 participants said yes, and ten said no. So, most participants need this competency in their

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[10] An email was sent to all alumni who graduates between June 2017 and September 2020 and who registered themselves at Alumni Relations, which is an organization at the TU Delft who organize events for alumni. They also offer help career-wise. Next to that the author also contacted graduates via LinkedIn.

current job. The participant who scored below three said that this competency is not needed in his/her/their current job.

Table 22 presents the reasons why participants are able to work with such situations.

Table 22 Facilitators of Dealing with Uncertain and Unpredictable Work Situations obtained from the survey

Based on your answers, you are able to deal with uncertain and unpredictable situations. What do you think the reason for this is?				
I am able to use my network to deal with uncertain and unpredictable work situations	I receive help from colleagues to deal with uncertain and unpredictable situations	I receive feedback, which helped me deal with uncertain and unpredictable work situations	I am open to change myself when confronted with uncertain and unpredictable work situations	Other
4	19	13	24	1

From this, we could say that being *open to change* is by far the most important facilitator for the participants, as 24 of the 32 choose this option. Next to that, receiving help from colleagues also constitutes to this competency. One student also mentioned '*Extra-curricular activities (student/study associations, dorms, time spent abroad) prepared me for dealing with changing conditions. I think this was a larger factor than my actual courses.*', which indirectly says that the study programme did not teach the participant to deal with such situations.

The results show that most participants (25 out of 31) believe that the programme did not teach their students how to deal with uncertain and unpredictable work situations. Most of them also believe that the study programme is not responsible for it (26 out of 31). So, we might say that the graduates learned this competency outside the university like one participant mentioned before. It may also be that the students do learn this competency at their study programme, but fail to acknowledge this as it may not be as clearly presented during courses.

The next section presents the results for the competency *Learning new work tasks, technologies and procedures*.

6.2.1.2 *Learning new work tasks, technologies and procedures*

Learning Work Tasks, Technologies and Procedures involves keeping an eye out on developments related to the job and update skills and knowledge accordingly.

Table 23 presents the mean, min, max and standard deviation of all the survey results for learning new work tasks, technologies and procedures.

	Mean	Min	Max	Standard deviation	N	=<3	>3
Learning new work tasks, technologies or procedures	4.2429	3.20	4.8	0.49697	28	0	28

In total, 28 participants rated the statements of the competency, so in total 5 participants quit the survey. All the participants scored an average above three, which means that they believe they have this perceived competency.

Almost all participants (26 out of 28) need to learn new work tasks, technologies, and procedures to do their job properly. The two participants who said they do not need this competency at their job are a PhD student at a university and a teacher in high school.

Table 24 presents what participants believe the reasons are that they are able to learn new work tasks, technologies and procedures.

The table shows that *having freedom at their job*, and *doing projects* is seen at the most important two reasons why participants have this perceived competency, as 20 out of 28 choose these two options. Next to that, collaborating with others and having freedom are also very important reasons.

Most participants believe that the programme taught them to learn new work tasks, technologies and procedures (20 out of 28) and that the programme was also responsible for it (23 out of 28).

Table 24 Facilitators for learning new work tasks, technologies and procedures obtained from the survey

Based on your answers, you are able to learn new work tasks, technologies and procedures. What do you think the reason for this is?	
I did projects at the company where I learned new tasks, technologies and procedures	20
I receive help from colleagues or managers, from who I learn new things	11
I use my network to learn new work task, technologies and procedures	2
I did a training, where I learned new things	10
I have the freedom at my job to do things differently, i.e., my manager inspires me to try out new things	20
I do new challenges, where I learn new tasks, technologies and procedures	12
I participate in work situations with others, where I learn new things	14
I collaborate with others, from who I learn from	18
I have a lot of freedom at my work, to focus on specific aspects of the job where I learn new things	16
Other	3

Other: *I am a 'smart' person, I founded my own company, so learning new tasks is required. Fortunately, most skills I need can be learned online, none of the above*

The three people who believe that the study programme did not teach them how to learn new work tasks, technologies and procedures, do believe that the study programme is responsible to teach them this competency. All three people also say they need this competency in their job. Two out of the three made it to the end, and one of the two works as an analyst at an European investment bank and the other is a researcher at an educational institution.

Overall, we could say that most participants believe they know how to learn new work tasks, technologies and procedures. Most of them believe they need this competency in their job, that the study programme taught them this competency, and also that the programme was responsible for it.

6.2.1.3 Solving problems creatively

This competency involves creating new and innovative solutions to problems, and assess different type of solutions available.

As shown in Table 25, most participants believe they have this perceived competency, as 25 of the students have an average perceived competency above three, and three students below or equal to three. The standard deviation is a bit higher than the previous analysed competencies.

However, when analysing the results, Qualtrics did not process the average correctly, and two people with a score of 3.2 were also processed as having an average below three.

Table 25 Mean, min, max and standard deviation for Solving Problems Creatively

	Mean	Min	Max	Standard deviation	N	=<3	>3
Solving Problems Creatively	4.1786	2.80	5	0.72488	28	3	25

Most participants need this competency at their job (24 out of 28).

In total, 25 participants had an average above three. Most of the 23 participants who were processed as having an average above three say that *doing projects*, or *having a lot of freedom* enables them to solve problems creatively, as shown in Table 26. Again, doing projects is seen as an important facilitator as it was for learning new work tasks.

Table 26 Facilitators for Solving Problems Creatively obtained from the survey

Based on your answers, you are able to solve problems creatively. What do you think the reason for this is?	
I know which problems need creative problem-solving	9
I did projects, which taught me how to solve problems creatively	16
I have a lot of resources at work available to solve problems creatively	5
I use criticism from my colleagues to use more creativity to solve problems	9
I have the freedom at my job to do things differently, i.e., my tasks are not necessarily fixed, or I have time	18
Other	0

One student filled in the survey partially and quitted the survey before answering what the reason for being able to solve problems creatively, five other students also filled the survey

partially but quit earlier than the person described before, and five had an average below three.

Everyone (also the graduates who were not adaptable) got the question *'was the study programme responsible to teach you to solve problems creatively?'*. However, this was not the case when analysing the results. The author made a mistake when creating the survey and forgot to present the question in such a way only participants with an average above three got this question. This also happened with Demonstrating Interpersonal Adaptability.

Again, from the participants who filled this part completely, most of them (16 out of 22) believe the programme taught them to solve problems creatively, and 18 participants (out of 27) also believe that the programme is responsible to teach them this.

6.2.1.4 *Demonstrating Interpersonal Adaptability*

Demonstrating Interpersonal Adaptability is being able to change your own behaviour in order to work well with others. It also encompasses the ability to be open-minded and listen and consider other's opinions and change your own point of view when it's convenient to do so.

The mean of the averages per participant for Demonstrating Interpersonal Adaptability is above average, as could be seen in Table 27. However, the mean is lower, and the standard deviation is higher than was previously analysed with the other competencies. The standard deviation is higher than Solving Problems Creatively. The reason for the difference is in comparison with the first two competencies is that this competency has more participants with an average below or equal to three. With Solving Problems Creatively, the standard deviation is higher because more participant had a lower average. Of 25 participants, only two participants have an average lower than or equal to three.

Table 27 Mean, min, max and standard deviation for Demonstrating Interpersonal Adaptability

	Mean	Min	Max	Standard deviation	N	=<3	>3
Demonstrating Interpersonal Adaptability	3.9360	1.80	4.80	0.71115	25	2	23

Most participants (21 out of 25) believe that they need to demonstrate interpersonal adaptability to properly carry out their job.

In total 23 participants have an average above three. Most students believe that they know which skills to use in social interactions to demonstrate interpersonal adaptability, but they also believe that because they interact with colleagues on a daily basis that they know how to.

Table 28 Facilitators for Demonstrating Interpersonal Adaptability obtained from the survey

Based on your answers, you are able to demonstrate interpersonal adaptability. What do you think the reason for this is?				
I did projects at a company where I learned to demonstrate interpersonal adaptability	I interact social on a daily basis with my colleagues or managers to know how to demonstrate interpersonal adaptability	I know when to demonstrate interpersonal adaptability	I know which skills to use in social interactions to demonstrate interpersonal adaptability	Other
7	11	9	12	1

Most participants (16 out of 22) believe the programme did not teach them to demonstrate interpersonal adaptability, and most of them (15 out of 24) also believed that the programme was not responsible to teach them so. Three participants who said that the study programme did not teach them this competency, believe that the programme was responsible to teach them this competency. One participant had it the other way around, so this participant believed that the programme taught them to demonstrate interpersonal adaptability, but were not responsible to do so.

6.3 Chapter Conclusion

Adaptability was chosen as the concept of thesis, because it may help narrow the gap between programme and professional career, as adaptable people are able to deal with new, uncertain and unpredictable situations, which graduates encounter at the start of their career.

This subsection answers SQ2.

2. *What barriers and facilitators do AM graduates encounter to adapt to activities in their job?*

As told before, the survey was used to find out what inhibits and enables students to be adaptive. We called these items barriers and facilitators respectively. These barriers and facilitators were found by analysing interview transcripts from alumni, but also with the help of literature. We used these items in the survey to find out what the participants believe enables or inhibits them to be adaptive. The results are used to create a definite list of barriers & facilitators of the adaptive competencies for AM graduates. They were also used to determine a direction for a solution.

To obtain the barriers, we asked the participants with an average below or equal to three what they think the reason is they do not fully have this perceived competency yet. Each competency has its own unique set of barriers, which could all be found in Table 19 and Table 36. Not a lot of participants had an average below or equal to three, so no hard conclusions could be made about the barriers. Even though these participants did choose some items over the other, due to the number of participants any conclusion would not be valid. The results when the average was below three is found in Appendix G2.

The participants with an average above three were asked what the reason for this could be. Most students had an average above three, so conclusions could be made for each competency. The most chosen options per adaptive competency are presented in Table 29, which answers SQ2.

Table 29 Facilitators of the four adaptive competencies Dealing with uncertain and unpredictable work situations, Learning new work tasks, technologies and procedures, Solving Problems Creatively, Demonstrating Interpersonal Adaptability most applicable for Applied Mathematics graduates, which are obtained from the survey

Dealing with uncertain and unpredictable work situations	Receiving Help
	Open to Change
Learning new work tasks, technologies and procedures	Doing Projects
	Having Freedom
	Collaborate with Others
Solving Problems Creatively	Doing Projects
	Having Freedom
Demonstrating Interpersonal Adaptability	Participate in social work situations
	Situation

6.3.1   Solution Direction

These last chapters, we focused on what adaptive competencies graduates might have after graduating (Chapter 5) and what might inhibit or enable students to be adaptive (Chapter 6 & Chapter 7). The results of the survey show that most graduates believe they have all four perceived competencies, and Table 29 presents the facilitators per adaptive competency, which the graduates believed were most relevant.

Table 30 shows that most graduates believe that the study programme taught them to learn new work tasks, and they were also responsible for it. Most students also believed the same for solving problems creatively. Next to that, most graduates do not believe the programme is responsible to teach them how to deal with uncertain and unpredictable work situations, and that the programme also did not teach them how to deal with such situations. Most graduates also believed the same holds for demonstrating interpersonal adaptability.

From this, we could conclude that the graduates believe the adaptive competencies *Dealing with Uncertain and Unpredictable Work Situations* and *Demonstrating Interpersonal Adaptability* are not yet present in the programme, even though the exit qualifications say otherwise. These qualifications tell that students will have these competencies after they finish the master programme. For this reason, we decided to look into these competencies and a way to include them in the curriculum.

Table 30 The number of students who believe the programme is or is not responsible to teach them these competencies as well as if the students believed the programme taught them these competencies

	Dealing with uncertain and unpredictable work situations		Learning new work tasks, technologies and procedures		Solving Problems Creatively		Demonstrating Interpersonal Adaptability	
	Yes	No	Yes	No	Yes	No	Yes	No
Did the study programme teach you	6	25	20	8	16	6	6	16
Was the study programme responsible to teach you to	5	26	23	5	18	6	9	15

7 Improving the AM master programme

Due to the technological developments over the past years, jobs are constantly changing, and becoming more innovative, flowy, and non-static. People no longer do one specific job for 40 years, but they hop from job to job. Overall, people no longer are routine experts, but they are adaptive experts, experts who are able to adapt themselves in new and changing environments. For graduates of the master programme Applied Mathematics, the same will hold. For this reason, the concept adaptability was introduced in this thesis, to narrow the gap between the master programme Applied Mathematics and the labour market. The survey obtained elements that enables graduates to improve themselves in the four adaptive competencies.

The results showed that almost all graduates need these four competencies in their job, which means that future graduates may also need all or a combination of them at their future job. So, it's important for students to gain some experience and practice them before they enter the professional labour market. However, two adaptive competencies were most relevant to further investigate.

This chapter describes how the two adaptive competencies *Dealing with Uncertain and Unpredictable Work Situations* and *Demonstrating Interpersonal Adaptability* could be included in the AM programme. Two courses, where students could gain experience on the professional career, were investigated, and after interviews one course was chosen. For this course a tool was developed that would prepare students better for their professional career. A preliminary version of it was discussed with two relevant staff members to find out if this tool has added value for the programme and if it could be implemented in the course.

In short terms, the programme should focus more on the two adaptive competencies *Dealing with Uncertain and Unpredictable Work Situations* **and** *Demonstrating Interpersonal Adaptability* **in the curriculum.**

7.1 Methodology

7.1.1 Course Selection

During the interview, a student mentioned Mathematical Data Science. She said "mathematical data science is truly a gold course. They have to keep it. I learnt almost everything I did in my graduation and later on in that course." So, we decided to look into the possibility to add something in this course. However, during an interview with a teacher and a student, we came to the conclusion that the students already encounter so much uncertainty during that course, as well as all the courses next to this one. For this reason, we decided to choose another course.

The other course is the internship. The internship serves as a way to familiarize one with the labour market, but at the moment the students only focus on the hard skills, not on soft skills, like on the competencies *Dealing with Uncertain and Unpredictable Work Situations* and *Demonstrating Interpersonal Adaptability.*

7.1.2   Design Tool

7.1.2.1   Semi-structured interview

Three interviews were held to find out what could be added to the programme to prepare students better for their professional career. Firstly, an interview of one hour was held with a staff member (Staff Member 4) and a student (Student 1) to talk about the course Mathematical Data Science. After that, a staff member who is among others responsible for the curriculum was interviewed to discuss the outcomes of the thesis and what their opinion is on the two competencies we want more focus on in the programme. After that, a staff member of the internship was interviewed to talk about the advice that was developed. During the interview, we discussed a preliminary version of the tool with the staff member and obtained feedback, after which we used the interview to complete the tool.

When the first interview with Staff Member 4 and Student 1 was held, Staff Member 4 said that the students already have to do so much, and there is also stress in that time. "I would like to say that is hard enough that nothing needs to be added." (Staff Member 4) So, with this being said, this course does not have a lot of space to add something, which could help narrow the gap

7.1.2.2   Design criteria

To develop a tool, several design criteria were developed that were considered to be important for the tool. These requirements were developed with the use of the interviews as well as with literature on Behaviour (Fogg, 2009), on Motivation (Deci & Ryan, 2000), and on Acceptance of Technology (Kulviwat et al., 2007). The articles used to develop the criteria are found by talking to students from the SEC programme and from previous courses within the SEC programme.

7.1.2.3   Tool development

After two interviews, a tool was developed that prepares students for their internship as well as their professional career. This tool focusses on creating awareness on possible situations students might encounter during their internship or professional career, on improving or developing two adaptive competencies within students, and on motivating them to think of soft skill development needed in their professional career.

7.2 Outcomes

7.2.1 Course Selection

The master Applied Mathematics offers a mandatory internship. Students could either choose between doing an internship as part of their free non-mathematics electives, as part of their master thesis, or both. As told many times throughout this thesis, the internship serves as a way to familiarize the students with the labour market, and "gain experience as a mathematician in a non-mathematical environment." (Lopuhaä, 2019, p. 13)

At the beginning of the internship, students have to contact the internship coordinator, who determines if the internship is adequate, after which the student start. At the end, they have to submit a report on what they did and a report on what they have learned from it. The second mentioned report is for the students of the AM programme, who still have to do an internship. This report serves as an example for others, and these students could find internships through them.

A couple years ago, the programme hosted presentation sessions for students who still had to do their internship. This way, students knew what was possible for their internship. Next to that, it was also a way to prepare them for their internship. (Interview 1 Staff Member 2) During the session, students who already did an internship, gave a presentation about what they did, where they did it and how they experienced it. However, after a while, because it was not mandatory, students did not show up, so the programme decided to end it.

Although, the programme focused on preparing students for their internship, the used method, i.e., the presentation session, was not successful, and they eventually stopped it. The layer we would like to add is an addition to the internship, where students do not only focus on the hard skills but also on soft skills. These soft skills are linked to the two adaptive competencies.

7.2.1.1 Internship & competencies

Although, the internship serves as a great way to familiarize one-self with the labour market, some students still feel like the internship is something to cross off the list, instead of seeing it as a great opportunity to learn a new skill or to improve a competency. During the internship, students only focus on doing the internship and passing it, instead of on other personal aspects, like how do deal with this new environment, how do I communicate with my supervisor who is not familiar with mathematics, or how do I deal with the money and privacy aspects of the internship? Most students also say they did their internship at a specific company, because they wanted to improve their programming skills, or they were interested in a specific mathematical model, or they wanted to know how a bank looked like from the inside. In other words, most students focused on improving hard skills, or on experience, instead of soft skills. For this reason, it would be best to add a new layer to the course, where students do not only focus on doing the internship and on improving hard skills, but also work on personal competencies and try to improve it.

As seen in Chapter 5, graduates have to deal with several uncertain and unpredictable work situations at their current job. Students who still have to do their internship could already work on these situations, so they know how to deal with them before they encounter them at their internship or at their future job.

7.2.2   Design Criteria

Before this new layer could be fully developed, a list of criteria was developed. The criteria were developed to create a tool that would fit the programme best.
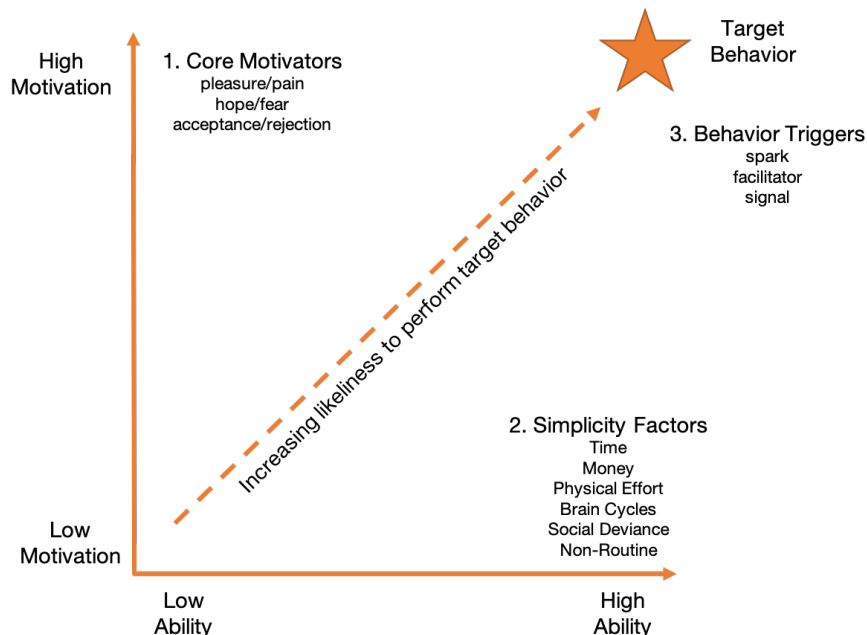
7.2.2.1   Literature

Figure 5 Fogg Behaviour Model (Fogg, 2009)

Fogg (2009) developed 'a new model for understanding human behaviour' (p. 1). This model described behaviour change as a product of three components: motivation, ability and triggers, which is easily translatable to criteria. They say that if a person has high motivation, is able to the task, and is triggered at the right time, then they are most likely to do so. There are different elements for each component, and one could use these when seeking a specific behaviour. One of the elements of motivation is fear. For example, if you want people to donate money to homeless children, a video of a bad environment the children are in focuses on fear as people do not want children to be in this environment.

So, when developing a tool to create awareness on the competencies, to have students develop learnings goals and to have them fill in the quiz, the tool requires specific elements in which motivation, ability and triggers.

However, often "increasing ability (making the behaviour simpler) is the path for increasing behaviour performance." (Fogg, 2009, p. 3) So, it is important for the behaviour to be so simple that there is no need for much motivation. Next to that, a trigger is also needed to have a person perform a specific behaviour such as a reminder.

Motivation is again built out of three components: autonomy, competence and relatedness, which is presented in the Self-Determination Theory (SDT) by Deci & Ryan (2000) This means that motivation grows whenever, people have enough autonomy to do the task, are able to do it (competence) and have the need to feel belonged and connected with others.

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One important item for intrinsic motivation is that when people need to perform a specific activity, and they need to have an intrinsic interest in the activity, otherwise, they will not perform the task. Thus, it is important that students have enough freedom within the given task, are able to do the task, and have the interest to do it. Relatedness seems not to be relevant for this tool, as the students do the internship for themselves and alone, so they are not necessarily related to someone specific.

Another interesting article is an article on Consumer Acceptance of Technology (CAT) written by Kulviwat et al. (2007). This article proposes a new model for the acceptance of technologies by consumers. It combines two models, Technology Acceptance Model (TAM) and Pleasure Arousal and Dominance paradigm of affect (PAD).

The tool that will be designed could be seen as a new technology which students of the master programme Applied Mathematics need to use. Figure 6 presents the Consumer Acceptance of Technology model. Three cognition elements are Relative Advantage, Perceived Usefulness, and Perceived Ease of Use. When a tool has these three elements, the attitude towards adaption is high, which influences the adoption intention. Next to that, Pleasure (entertainment potential), Arousal (excited feeling), and Dominance (being in control), also influences attitude toward adoption positively.
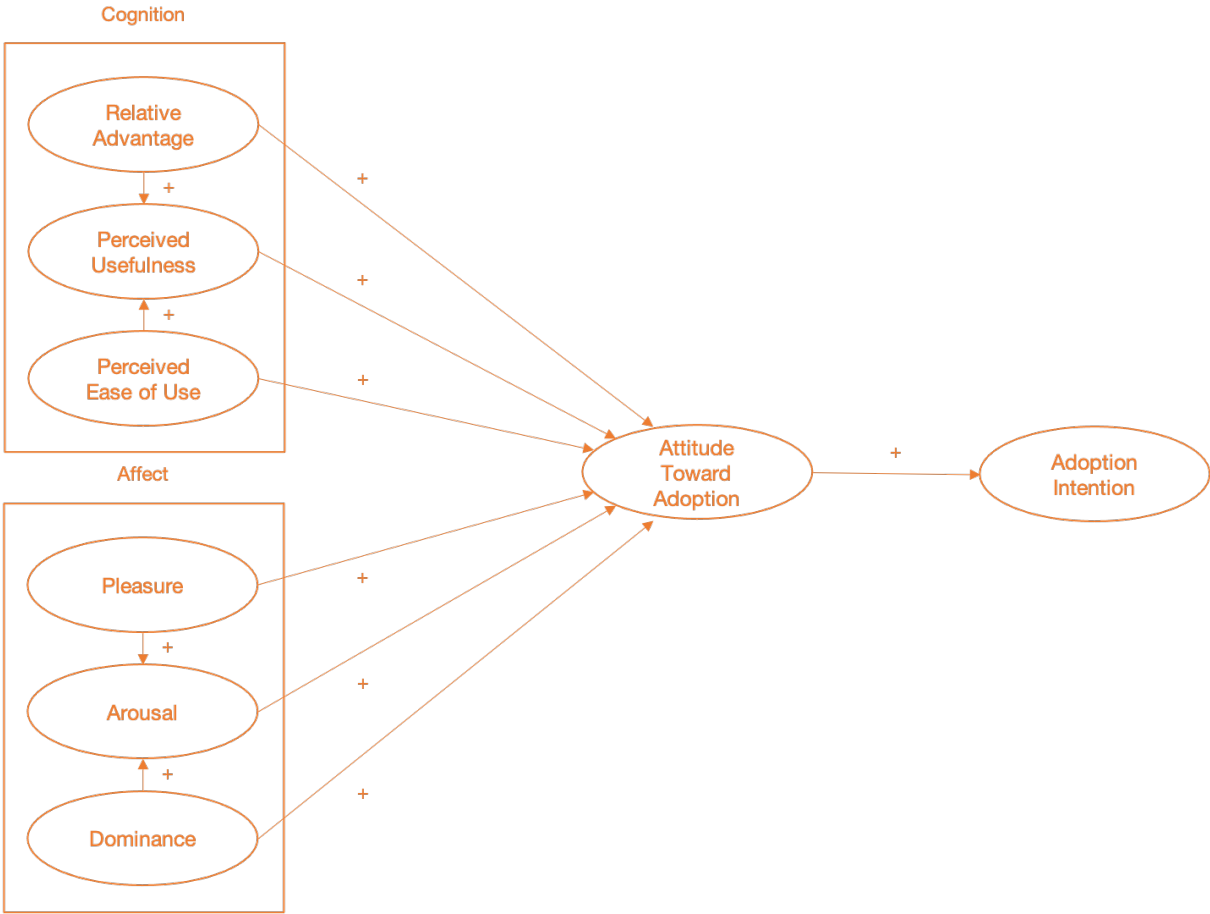

Figure 6 Consumer Acceptance of Technology Model (Kulviwat et al., 2007)

The described elements of the Fogg Behaviour model, the Self-Determination Theory, and the Consumer Acceptance of Technology are transformed to criteria. The complete list of criteria is presented in Textbox 2.

Attainability of the tool

Is the tool attainable for the programme? Do they have enough resources, time and people to further develop it?

Knowledge of the teacher

Does the teacher have enough knowledge to assist students?

Ease of use

Is the tool easy to use?

Relative advantage

What is the relative advantage to use it in comparison of not using it?

Usefulness

How is the quiz useful for the students?

Reminder (trigger)

How are the students triggered to use it?

Freedom (autonomy)

Do the students have enough freedom within the quiz?

Interest

Are students enough interested to do the quiz?

Students are able to do the task (competency)

Are students able to do the task?

Textbox 2 Design Criteria for tool development

7.2.3 Design proposal

As told before, the staff member tried to prepare students for their internship, by hosting presentation session. However, because little students showed up, they decided to end this. Another way to prepare students for their internship is to use an online tool, where students do not have to be present physically, but could prepare themselves when they have the time. The method chosen is an online quiz on Brightspace[11].

Online Quiz

Preparation for internship

Awareness on possible situations one may encounter

Development of personal learning goals

Internship

Working on personal and professional learning goals

Reflection

Self-assessment form

Reflect on personal goals process during internship

Figure 7 Aspects of the Internship Tool

Firstly, the students have to find an internship of their liking. It is expected that students will choose an internship based on the hard skills they would like to improve. In other words, focusing on these hard skills could be seen as working on professional learning goals.

Secondly, the students have to do an online quiz on Brightspace a week before they start their internship. The goal of the quiz is to increase awareness on possible scenario's they might encounter at their internship or at their job. Next to that, it also serves as a way to get familiar with the two competencies they will eventually practice during their internship.

During the quiz, the students have to respond to relevant situations and examples of how their professional career might look like related to the competencies. After they responded to several situations, they receive tips on how to deal with these situations. These tips are the facilitators mentioned by interviewed alumni or chosen by alumni in the survey. After they received tips, the students have to develop personal learning goals focused on the adaptive competencies. There will be several situations sketched which they should use when developing these learning goals. At the end, they receive a summary of their developed learning goals they will work on.

During the internship, the students will focus on their professional and personal learning goals, and carry out the assignment by the company.

Finally, after they have done the internship, they have to submit the evaluation form evaluated by the company, a report on what they did during their internship, a small report

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[11] Brightspace is an online collaborative and learning environment used at the TU Delft.

on what they have learned, and they have to fill in a self-reflection form, where they reflect on their personal learning goals.

A way to actually try and focus on the adaptive competencies during their internship is to develop personal learning goals. In general, there is a link between goals and performance. (Lunenburg, 2011) Lunenburg said that "individuals who are provided with specific, difficult but attainable goals perform better than those given easy, nonspecific, or no goals at all. At the same time, however, the individuals must have sufficient ability, accept the goals, and receive feedback related to performance" (p. 1) In the article, he developed a model of goal setting and listed suggestions for managers, who could use the information to increase employee's motivation and performance.

From this article, we see that goal setting is useful to increase performance among employees, and Lunenburg also provides useful suggestions for organisations to increase that. Although this article is for organisations, the information is also useful for educational purposes and could provide tips for students or lecturers to help students develop goals. An important suggestion they mention is that receiving feedback on the goal attainment is a must. Feedback helps people to understand why changes are needed to improve, and it also shows how they are doing at the moment.

7.2.3.1 The tool
The developed tool is an online quiz for master Applied Mathematics students who will do an internship in the nearby future.
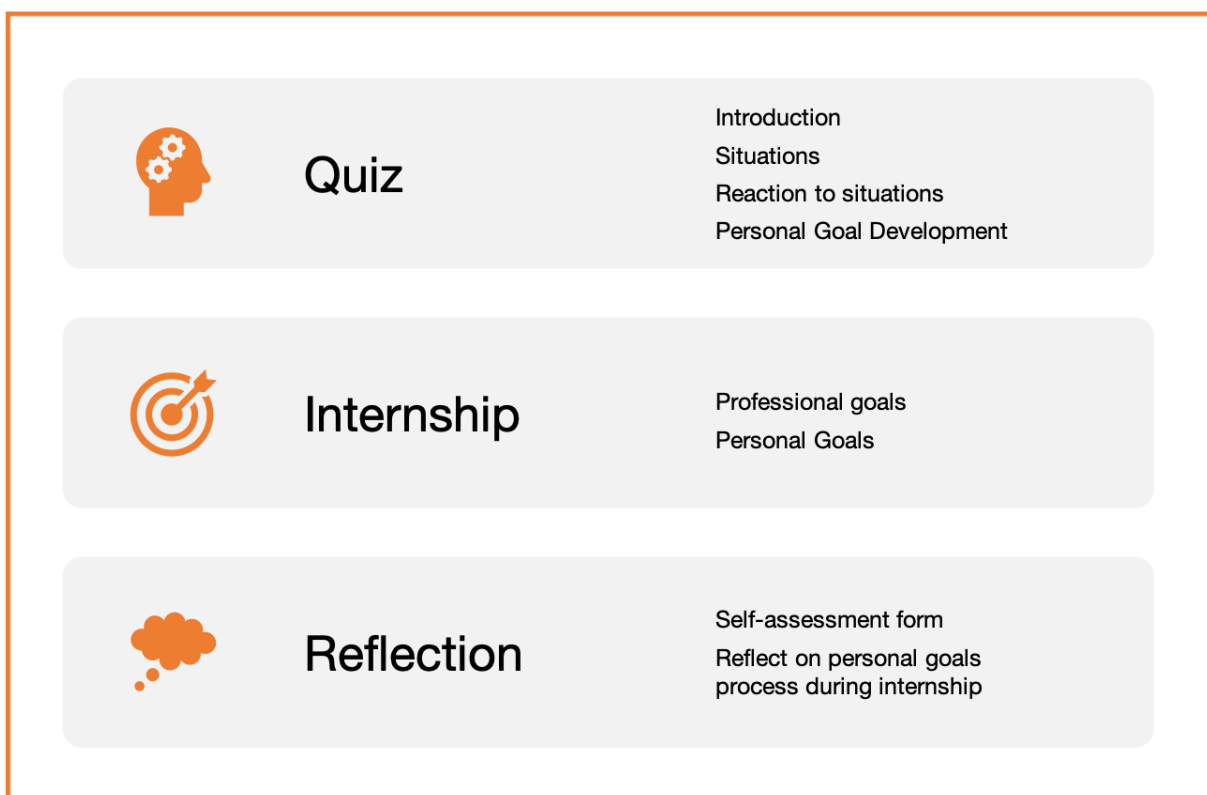
Figure 8 Tool outline

Introduction: What is the quiz?

Here, students will read an introduction, where they will find out the quiz is about.

The outline of the quiz:

- Explanation of the internship
- Information about study goals
- Situations
- Developing personal learning goals
- Summary

The quiz will take around one-hour. At the end, they will have to reflect on these personal learning goals.

Internship: Why is it important?

In this section, the students receive information on what the internship entails and what the overall goal is. They receive the following information they get is: *The internship serves as a way to gain experience in a professional setting, but also "to gain experience as a mathematician in a non-mathematical environment"* (Lopuhaä, 2019, p. 13)*. "The project is carried out at an institute where the mathematics itself is generally not of primary interest but merely a tool to solve practical problems."* (*WI5118 Internship 18 EC | Online Study Guide*, n.d.)*.* Hopefully, the quiz makes them aware on what they could encounter in the future as an intern or as a fresh graduate. So, it serves as a way to prepare them for their future.

To prepare themselves, the students will have to respond to situations graduates encountered during their internship or at their current job, which were difficult or very different from what they were used to when studying. The students have to develop personal learning goals based on these situations. The situations are linked with the two adaptive competencies, which will be discussed later on. Thus, the students will develop goals to become better at these adaptive competencies.

Each student has a specific goal in mind when they start their internship. The students might like to improve practical skills, like programming, or would like to know how a specific mathematical method works in the real world. However, the internship could also serve as a way to improve personal skills or gain new ones, like collaborating with non-mathematicians and dealing with feedback. Below a list of the internship study goals are presented which are found on the Online Study Guide (*WI5118 Internship 18 EC | Online Study Guide*, n.d.). The last four study goals are added.

Textbox 3 Internship Study Goals mentioned on the Online Study Guide TU Delft (*WI5118 Internship 18 EC | Online Study Guide*, n.d.) with four added study goals

Situations: Adaptability

During this quiz, they will learn more about what they might experience during your internship or at your future job. These situations are linked to two adaptive competencies *Dealing with Uncertain and Unpredictable Work Situations,* and *Demonstrating Interpersonal Adaptability.*

> **Dealing with Uncertain and Unpredictable Work** Situations involves effectively adjusting work tasks and plans, and taking reasonable action when a new and unfamiliar situation arises. To deal with such situations, graduates said they are open to change, and receive help from colleagues, or their supervisors.

> **Demonstrating Interpersonal Adaptability** means being able to change your own behaviour, goals and opinion in order in order to work well with others. It also encompasses the ability to be open-minded and listen and consider other's opinions and change your own point of view when it's convenient to do so. To practice and become better in demonstrating interpersonal adaptability, graduates participated in social work situations, and said they know in which situations they needed to demonstrate it.

After a situation is presented, the students are asked to share how they would deal with such situations and what they need to deal with it (help from managers or colleagues, training, etc.).

To find the most relevant situation for the students, the students are asked to rate and answer a couple of questions. Based on these answers, the students will receive two situations in total.

In the textbox below, we presented four situations they will use to develop personal learning goals for your internship. These four situations are fictional, but based on true stories.

Textbox 4 Tool situations

The students will have to choose two situations they believe are the most relevant for their internship or professional career. To help them, they could answer four questions which lead to situations which are most relevant for their case.

Textbox 5 Tool situation selection

If students answer in such a way that no situations are relevant, they could use situation 1 and 2. If students have more than two options, the students have to choose 2.

Personal Learning Goals: Developing personal learning goals

After the students answered these questions, they have to develop personal learning goals. These goals will help them focus on improving these competencies. They have to read the situations carefully and answer the questions related to the situation. After that, they develop a personal learning goal based on the answers to the questions and on the following question: what would you like to learn during your internship based on this situation?

They are advised to use the SMART method to develop attainable goals:

- S: Specific
- M: Measurable
- A: Attainable
- R: Relevant
- T: Time

> **Situation 1 (Example)**
>
> *Internship at IT company: a graduate had to do a project and use artificial intelligence*
>
> Paulo graduated about a year ago and is currently a PhD student. In 2018, he did an internship at an IT company, where he developed a model using artificial intelligence. During his internship, he found out that the company did not care about how the method exactly worked. "I had the data, so I just had to clean it up […] and that [method] would just give an answer. At one point I got it right with 70% and they were over the moon." Even though the company was very happy, Paulo was not. He said "I was not very pleased with it. […] I really had no idea why it worked."
>
> During his internship he learned that the industry is result-oriented, i.e., it does not matter how you got the answer, the only thing that matters is getting an answer. In other words, the mathematics used in the industry is less than used at the study programme. Paulo was not happy with this part of the job, and decided to do a PhD after graduation. What would you do in Paulo's case?
>
> > *How would you deal with not using all the mathematics you are used to?*
> >
> > *What would you do if you were in this situation?*
> >
> > *How would you feel if you were in this situation?*

<div align="center">Textbox 6 Example Tool Situation</div>

Other examples of the situations described are found in the Appendix J.

Other examples they might have not seen are also presented in the tool to show them what they could encounter.

> **Dealing with uncertain and unpredictable work situations**
>
> - A company also has a political side.
> - Project from the industry also involves money and privacy factors.
> - Companies are more focused on having results, instead of on having the best solution.
> - A company requires different level of transparency. At the study programme, students are used to writing everything down, also the failures. This is different in the industry, because they are not interested in the failures, only in the successes.
> - A team could gain new insights, which requires more research and time.
> - Projects are not perfect as at the university.
> - Project from the industry mostly use simpler models.
> - A project cannot be more mathematical advanced. In other words, you are not always able to add more mathematics.

<div align="center">Textbox 7 Examples of situations where graduates needed to deal with uncertain and unpredictable work situations</div>

Textbox 8 Examples of situations where graduates needed to demonstrate interpersonal adaptability

Summary: What do you need to deliver?

At the end, they receive a summary of their developed personal learning goals, and what they have to submit. They are also reminded that they need to keep these goals in mind while you do the internship, because at the end of the internship they have to fill in a self-reflection form, where they will reflect on their goals.

Here is a complete list of the items they need to submit/do if they would like to receive the credits:

- Quiz
- Report about what you did at their internship
- Report on what they have learnt
- Evaluation form external supervisor
- Self-reflection form on personal learning goals

Feedback

As mentioned in Sub-Chapter 5.2.4 receiving feedback is important to understand why changes are needed to improve, and it also shows how they are doing at the moment. It is therefore important for the students to receive feedback on their developed personal learning goals. The teacher should check if the goal is sufficient, if it is attainable, and if it relates to soft skills and not hard skills.

Self-reflection form: at the end of the internship

The Career & Counselling Services offers a reflection log form, which students could use 'to identify and reflect on their skills acquisition and development.' (*Reflecting and Recording | Managing Your Career by Career & Counselling Services TU Delft*, n.d.) This form keeps track of student's experiences. This form was used and altered to fit the purpose of this tool.

The original reflecting learning log is added in Appendix K. In the original reflection tool, the students have to reflect on the skills they gained during a specific event. Firstly, they have to explain the event; what happened, when did it happen, etc. Secondly, they have to reflect on the skills they have used and developed during the event, by first describing what they did good, then about what they have learnt, which is the third part of the form. Fourthly, they have to reflect on the future, by explaining what they would have done differently if the

event takes place again. Lastly, they have to explain what knowledge, skills or attributes they would like to change and improve.

This reflection tool starts with the student describing their learning goal. Secondly, the student has to describe the internship, by describing the tasks, how they practiced the learning goal, and how they felt about doing it. This is the same as the first part of the original form. Thirdly, they have to explain if they did well, which is the same as the second part. Then they explain what they have learnt the most, which is the same as the third part of the original. Fifthly, they have to explain what it means for their professional career. Lasty, they have to look into the future by explaining how they could use what they have learnt in their future career. The form has to be filled in from start to end.

Learning goal:

The internship

What were my tasks?

How did I practice the learning goal?

What were my feelings?

How well do I think I did on my learning goal?

What have I learnt the most?

Is there anything I would have done differently?

What does this mean for my future career?

How could I use what I have learnt in my future career?

Textbox 9 Self-assessment form questions

7.2.3.2 Criteria check

The tool satisfies all the criteria. A list of how it satisfies them is presented below.

Table 31 Design criteria check

Criteria	Check
Attainability of the tool *Is the tool attainable for the programme? Do they have enough resources, time and people to further develop it?*	The relevant staff member interviewed said that the tool could be implemented easily by them, as it does not take a lot of time for the student and they do not have to request permission higher up. The quiz could be implemented in Brightspace, which is already used by students and teachers on a daily basis for study purposes. The staff member said it does not take a lot of extra time to check the quiz and read an extra report, if there is a limit to the number of pages. However, the staff member said that to add this in the course, it will take some energy. To do this, they will have to get extra help, such as help from others, like the educational expert at the faculty, more time from the director of education, etc. Students who already did the quiz, could help next year as student-assistants.
Knowledge of the teacher *Does the teacher have enough knowledge to assist students?*	The teacher should have sufficient knowledge on soft skills and personal learning goals related to professional career, to provide good feedback. This element was added after Interview 2 with Staff Member 2, so it was not discussed if this was possible.
Ease of use *Is the quiz easy to use?*	The quiz is easy to use as the students have to follow the quiz from start to end and receive information they need to respond to, questions they have to answer, and they have to develop learning goals at which they are assisted (information on making goals SMART) Most of the time it is very passive, the students need to read information. After a while, it becomes more active, as students have to answer questions. Next to that, the quiz could also be conducted when the student has the time for it, but at least one week before the internship starts.
Relative advantage *What is the relative advantage to use it?*	At the beginning of the quiz, the students receive general information about the internship, why the internship is important and how the tool contributes to it.
Usefulness *How is the quiz useful for the students?*	The information about the internship and why it is important will also highlight the usefulness of this tool related to the internship.

Reminder (trigger) *How are the students triggered to use it?*	The students will be reminded by the internship coordinator to fill in the quiz when they contact him about the internship.
Freedom (autonomy) *Do the students have enough freedom within the quiz?*	The students have freedom when they answer the questions and respond to situations in the quiz.
Interest *Are students enough interested to do the quiz?*	We believe that students will find the quiz interesting, because it is a tool that will help them become better prepared for their internship, and also for their professional career.
Students are able to do the task (competency) *Are students able to do the task?*	The quiz is easy for students to follow, see *Ease of Use.*

7.3 Chapter Conclusion

This Chapter presented a tool that could help the master programme Applied Mathematics narrow the gap between programme and labour market. By being aware of the possible situations they could encounter, by developing personal learning goals and by reflecting on them, we believe the students will be better prepared for their professional career.

3. *How does the programme help students to learn to adapt to situations related to the professional career? What kind of courses do they offer to do so?*

The programme offers a mandatory internship for all students to do during their master programme, regardless of their specialization. During the internship, the students focus on improving hard skills, and less on soft skills, like communicating, or collaborating.

The course Mathematical Data Science is offered to students from the programme, which is a project-based course, where students work on a case from the industry. The case described a problem, which the students have to solve in a small group (around 6 people). They have to work together to come up with a solution and have contact with the case owner about the process. Each group also has a university supervisor who helps the group with the mathematical part of the case. Staff Member 4 said that this course kind of prepares students for their professional career. The students have to work together with other students to solve the case. So, the students have to work together to complete the course, during which they undoubtedly have to demonstrate interpersonal adaptability. The students also have to deal with uncertain and unpredictable work situations, for which a list is presented in Appendix I.

The internship as well as Mathematical Data Science both offer students a way to prepare themselves for their professional career.

4. *What type of tool could help the programme prepare AM graduates to be adaptive in the first 3 years of their professional career?*

To become more adaptive, an online tool is developed where students will become more aware on the situations they might encounter at their professional career. These situations are focussed on *Dealing with Uncertain and Unpredictable Work Situations,* and *Demonstrating Interpersonal Adaptability.* Developing personal goals based on these competencies, working on them during an internship and reflecting on them afterwards, might increase the student's awareness on the useful of these competencies in their future job, as well as it might improve their own competencies. The tool is an online quiz which the students will fill in a week before they start their internship. After the internship, the students have to submit a self-assessment form, where they reflect on their personal learning goals and how they will use it in their future career.

A way to check if students became more adaptive is to handout a survey before and after the internship, that determines how adaptive they are on the four adaptive competencies. If the results improved, we know the student became more adaptive.

Mathematical Data Science

During Mathematical Data Science, the graduates also encounter several uncertain and unpredictable (work) situations, and need to demonstrate interpersonal adaptability, so they already become more adaptive by following this course. However, Mathematical Data Science is an elective, which means that only the students who choose to do this course, could practice these competencies.

During Mathematical Data Science, students will encounter several uncertain situations, like the examples shown in Textbox 10 in Appendix I1, and they will also have to work with others and thus encounter interpersonal interactions with fellow students. During these interactions, the students demonstrate interpersonal adaptability to collaborate well with others. So, students who follow this course already become more adaptive. Next to that Lopuhaä mentioned in the Critical reflection that students were less "satisfied with the attention paid to communication and collaboration." (2019, p. 20). For this reason, the programme could also focus more on collaboration within the mathematics programme and how to increase effective collaboration within the projects.

A way for the programme to focus on collaboration is facilitate more project-based courses like MDS. During the interview with the Staff Member 4 and Student 1 said that adding more collaboration in courses would prepare students more for their professional career. Staff Member 4 explained that it costs a lot of effort to find projects from the industry, and this brings uncertainty along. So, to decrease this uncertainty, the teacher or a group of teachers together could also develop societal relevant projects which mimics the industry. A course like this is already used in the bachelor, i.e., Modelling A and B in the first and second year of the study programme. (*Bachelor Applied Mathematics | Curriculum 1st Year*, n.d.; *Bachelor Applied Mathematics | Curriculum 2nd Year*, n.d.) This way, the students practice and gain experience in collaborating within a project, but they also learn more about the type of projects done within the industry.

8 Discussion

Tynjälä (2008) mentioned in his research that "Recent research on the outcomes of education, particularly at the tertiary level, has shown that there is a gap between the knowledge needed at work and the knowledge and skills produced through formal education." (p. 131) Therefore, it is important to prepare students for the labour market. The results of the National Student Survey 2019, the NSE 2019, show that the students or graduates of the master programme Applied Mathematics at the TU Delft are not unanimously satisfied with the preparation offered for the labour market, which was mentioned by Lopuhaä (2019). This thesis tries to narrow the gap between master programme and labour market by investigating the concept adaptability in the workplace. Research shows that two adaptive competencies, *Dealing with Uncertain and Unpredictable Work Situations,* and *Demonstrating Interpersonal Adaptability,* are the most relevant competencies to be included in the master programme. The developed tool could increase a student's individual adaptability, by focusing on personal learning goals related to the two competencies during their internship.

8.1 Research

8.1.1 Theory

Adaptability or adaptivity is the ability to settle more easily in a new and unfamiliar environment. (Carbonell et al., 2014; Charbonnier-Voirin & Roussel, 2012; Pulakos et al., 2000, 2006; Savickas, 1997) The framework used by Pulakos et al. (2000) was used to find out how adaptable the students are, which adaptive competencies they need in their work and om which adaptive competencies the programme should focus on more to make them more adaptable. The framework developed by Pulakos et al. (2000) was used to determine which adaptive competencies apply in the workplace where adaptability is highly needed, like in the army. We asked graduates if the four competencies used in this thesis are needed at their current job, which was mostly the case, but not all graduates needed all competencies. This research used four adaptive competencies which are applicable in the workplace. There is no framework used where adaptive competencies are needed in education, nor did we use literature on adaptive competencies in education. Tordai & Holik (2018) mention that "non-technical and interpersonal skills are crucial for engineers" (p. 32), and that competence has become more important at universities for their students to succeed in the workplace. Tordai & Holik (2018) measured attributes and competencies during student's academic careers. The students had to rate competencies, and the importance of them in their future professional career. Tordai and Holik developed a list of competencies by looking at job vacancies and considering other competency assessments in higher education. One of the competencies was 'Adaption to change', which was rated highly. For students to become more successful at their future job, Tordai and Holik (2018) recommend higher education to focus more on the competence development of, among other skills, self-knowledge. So instead of focusing on only adaptability, it would also have been interesting to focus on other personal and interpersonal skills needed at their future jobs, which are mentioned in vacancies or by the industry themselves (interviewing them).

The framework by Pulakos et al. (2000) mentioned eight dimensions, from which four were seen as most applicable. These eight dimensions were linked with the exit qualifications to determine which adaptive competencies apply for the AM graduates. The link was made

without the help of students, graduates, staff members of the master programme or the industry, which could validate if the competencies really apply, and are relevant for the graduates. Therefore, it may be the case that more or less competencies be applicable.

When considering the framework and the dimensions' definitions in Table 6, three adaptive competencies are already not applicable for the graduates and not relevant for the programme, such as: *Demonstrating physically oriented adaptability, Handling work stress, and Handling emergencies or crisis situations.* Instead of linking the competencies with the exit qualifications to determine which of them were applicable for the graduates and relevant for the programme, we could have also looked at the competencies and see which were not relevant in general. Demonstrating physically oriented adaptability is: *Adjusts to various physical factors such as heat, noise, uncomfortable climates, and difficult environments.* As Pulakos et al. (2000) measures the dimensions among members of the army, this competency is applicable for them, and not for AM graduates. The same holds for Handling emergencies or crisis situations, which means: *Reacts appropriately and decisively to life-threatening or dangerous situations*. Next to that, is it the programmes task to teach students how to handle work stress, or is it something the students should practice more at their own? If we did this, we were left with five adaptive competencies to test, which were more applicable for general workplace employees, and the linkage between exit qualifications and the framework was not needed.

8.1.2 Methods

Literature analysis

To find relevant literature about adaptability to find out what could narrow the gap, a literature review was developed. As is seen in Appendix H, different concepts were used to find literature, like adaptability, adaptive expertise, and resilience. These concepts were found to be relevant by the author herself but were not validated by experts on adaptability to find additional and more precise concepts related to adaptability. Next to that, there was no list with criteria used to determine which article was not applicable for this thesis. It would have been better to create a list of criteria like year of publication, citation, location, but also key words like health care or depression to remove irrelevant articles.

The literature to develop criteria for the tool was literature used in other courses or recommended by fellow students from the Science Communication master, who the author talked with to get feedback and help. It would also be good to find additional literature via SCOPUS or Web of Science about the development of a tool in an educational setting.

Interviews

This thesis gained a lot of qualitative data from different people related to the subject. In total 13 people were interviewed: 4 staff members of the master programme, from which 2 were interviewed twice; 2 CH board members; 1 staff member of Career & Counselling Services; 5 graduates; and one current student. Almost every interviewee has either a different role within the programme or university. Two out of the four staff members are responsible for programme content and structure. Two staff members are responsible for the internship course, and one staff member was responsible for the course Mathematical Data Science. Because of these different roles within the programme, each interviewee provided different

views on the subject and for which we thus gained more information on the matter. Next to that, the Career & Counselling Services and the study association also added different views.

The graduates also have experience in different sectors which provides different views on preparation for professional career, as well as what they experienced as difficult, new and uncertain at their current job, as was described in Subsection 5.1.1. Four of the five interviewees did the master specialization Stochastics, and one did Analysis. Not every specialization was thus considered in this thesis, which could influence the adaptive situations, barriers and facilitators the graduates described in Chapter 5. As an example: the track Computational Science and Engineering is more on the applied side and has the mandatory course Advanced Modelling. In that course, students have to work together with a team on a mathematical problem, where they have to develop a model to solve it. At the end of the course, the team presents the solution to the group. It may be the case that these students are more adaptive than others, because they followed other courses, and thus also encounter other situations as difficult, uncertain and unpredictable. The same holds for one of the sectors which was not covered: graduates who pursue a career in education or start another study programme. Although, it may have been better to consider all specializations, because the graduates gained experience in different sectors, different views on the workplace in different sectors have been considered. We did not focus on teachers, because they are the smallest group of sector of where graduates end up considering the results mentioned in the Critical Reflection (Lopuhaä, 2019).

Survey

Statements

The statements in the survey are developed with the definitions developed by Pulakos et al. (2000), and also statements written by Charbonnier-Voirin & Roussel (2012). These statements are not tested to see whether the statements measure the obtained concept, i.e., having the adaptive competence or not. This is called validity: "the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration." (Babbie, 2007, p. 148). There is face validity. When a statement is valid "on its face", in this case rating the statement "I am able to work in a changing environment" had something to do with dealing with uncertain and unpredictable work situations. There is also content validity "The degree to which a measure covers the range of meanings included within a concept." (Babbie, 2007, p. 150) Specific combinations of statements covers one of the adaptive competencies. From this, we could say that the statements are somewhat valid. The question remains if the statements for a specific adaptive competency cover the whole concept. (Charbonnier-Voirin & Roussel (2012) developed a scale which measures five dimensions of adaptive performance. This scale was developed qualitatively and quantitatively. The statements from this article are used and altered in this survey.

The survey was developed to determine whether students are adaptive or not. The articles used to develop the statements focus on adaptability in the workplace, a non-teacher workplace environment. For this reason, the statements were mostly industry related, so a graduate mentioned at the end of the survey that little attention was made on teachers. As most students pursue a career in the industry, the group of teachers is a relatively small.

(Lopuhaä, 2019) So although, the student makes a good suggestion, this thesis focussed more on the industry side and PhD of the labour market.

Barriers and facilitators

The barriers and facilitators obtained from the interviews and from the literature are chosen without considering the differences between type of the barriers, or the facilitators, and how we could use them to develop an advice. 'Open to change' is a different type of facilitator than 'receiving help', whereas open to change refers to someone's ability, and receiving help an external factor like a colleague or manager. Therefore, it is also difficult to use these barriers and facilitators to give an advice to the programme. Receiving help is relatively easy to put into an advice, namely that the programme could help students more often, or provide more feedback on projects, individually or in a group. Open to change, in that perspective, is a bit difficult, as that would mean offering guidance to help students become more open to change. It would have been better to look at items that are more related to some external factor, like receiving help, having freedom, doing projects or collaborate with others. These items are easier to implement, than the open to change, and knowing when to demonstrate interpersonal adaptability.

Perceived Competencies – graduates

The survey also shows that most participants believe they have these perceived competencies. Kruger & Dunning (1999) found out that people overestimate their abilities. In their article they explain that incompetent people are not able to recognize their poor performance, so they magnify it. Next to that, they also found out that competent people underestimate themselves. It may be the case, that the graduates are not fully competent, and overestimate their ability, or in this case, rate each statement very high. This is probably not the case for every graduate, but could be for some of them. If graduates overestimated their own perceived competencies, it may be the case that they do not possess the adaptive competency yet, which influences the outcomes of the survey. If they would have rated this more truthfully, it may be the case that more graduates had an average below three.

8.1.3   NSE

At the beginning of the thesis, several staff members from the programme, the study association and Career & Counselling Services are interviewed to find out how they prepare students for the professional career. From this, we observe four different definitions or outlooks on 'preparation for professional career'. So, the NSE questions could be interpreted differently by the students, which influences the results. The NSE could rephrase their questions or explicitly say what is meant with 'professional career' to have a better understand and interpret the results.

The NSE also does not have a satisfaction rate for internship and programme, which is about the preparation offered for the internship. The reason for this may be that not enough students filled in the survey to come to a conclusion. Our survey shows that most students are satisfied with their internship or master thesis at a company and how they are prepared for it. Students are less satisfied with the information provided about the internship report, and offered guidelines to pass the internship (not for the master thesis at a company). We conclude that most students are satisfied with their internship.

8.2 Generalisation

This thesis investigated the gap between master programme and labour market specifically for the master Applied Mathematics. During this thesis, it was found that two adaptive competencies were not yet present in the programme, for which a tool was developed. This tool is thus mostly applicable for the mater Applied Mathematics at the TU Delft, as the tool describes and uses situations experienced by graduates from the programme. To be able to use this tool for other programmes, one should first investigate what kind of adaptive situations those students encounter at their current job and on which adaptive competencies the programme should focus more. This could be done by interviewing graduates and sending out a survey, but also by talking to the industry and determine what the industry is looking for in a graduate.

Next to that, this thesis could be used for other Applied Mathematics programmes at Twente University or Eindhoven University of Technology, because these programmes are both focused on the application of mathematics rather than on focusing the application of mathematics rather than on focusing on theory, like a pure Mathematical Sciences at Utrecht University does.

This research focuses on adding focus on adaptive competencies in the internship. Some mathematical master programmes do not offer a mandatory internship in their programme like: Mathematics at Leiden University, Mathematical Science at University of Utrecht, Mathematics at University of Amsterdam, or Mathematics at the Vrije Universiteit Amsterdam, but at some of these programmes it is possible to do an internship at a company (Utrecht University, University of Amsterdam or at Vrije Universiteit Amsterdam). Two interviewees mentioned that the internship was added to the programme to prepare students more for a professional career in the industry, and to decrease the culture shock they encounter when they start working. When considering the NSE 2019, the scores on *internship and programme* for other mathematical programmes is lower than the scored for the master Applied Mathematics at the TU Delft (Eindhoven University of Technology) or non-existing, because they do not offer an internship. Another important finding is that the results of NSE 2019 show that the AM master programme at the TU Delft scores higher than all the other observed programmes on preparation for the labour market. So, it may be interesting to see what the influence of adding a mandatory internship would be in the Mathematics master programmes without.

8.3 Future research

Most students who participated graduated in 2019, which is a year ago. Another question arises: do graduates who work longer, are better in the adaptive competencies, than the ones who graduated more recently? Appendices G3. Education and

G4. Current Job G4. Current Job present information about participant's education and current job respectively.

This research does not obtain barriers, i.e., elements that inhibits graduates to be adaptive. Student said that they all have these perceived competencies, so the survey mostly obtains facilitators, i.e., elements that enables graduates to be adaptive. Next to that, the facilitators and barriers are found in interviews, where students described difficult situations or situations

which were different from what they are used to. The interview yields what they need or what helped them to overcome these situations. In total, five graduates were interviewed, from which 4 students did the master track statistics. Next to that, two graduates do a PhD at a university, another at a research institution, one graduate works at a bank, and another at a consultancy company. Although the jobs are different, and they work at different places, because most of them did the same master track, it could influence the situations they find difficult. So further research should be done with graduates from all the tracks, to obtain more situations in which they need to demonstrate interpersonal adaptability.

One alumnus did not have three of the four competencies. The reason for this is that the participant graduated in September 2020, and did not have any work experience so far.

In further research one could do additional interviews with alumni to obtain detailed information about these facilitators. For example, students choose having freedom, but what kind of freedom do they need? No deadlines? No fixed tasks? No hard-working hours?

Due to time constraints, it was not possible to test the quiz with a couple of students who will do an internship in the nearby future. Although, it was not tested, a relevant staff member of the programme was interviewed, and his feedback was used to develop the tool. To determine if the tool has it's intended effects, the tool should be tested among a group of AM graduates who still have to their internship. Firstly, the group of students have to fill in the quiz and provide feedback on the way it has been written, if the questions and assignments in the quiz are clear, and what their opinion is on the quiz in general, e.g., the goal. After the did their internship, they have to fill in the self-reflection form, and also have to provide feedback on that. After they have received the grade, the students will be interviewed by the staff member who is responsible for the quiz, to find out what additions/changes should be made, and also to check if the students see the added value of it. Afterwards, the staff member will make changes, and an improved version will be used afterwards.

8.4 Contribution to Science Communication

This thesis presents an internship tool to prepare students for their professional career, which may narrow the gap between programme and labour market. It indicates and presents a link between adaptive competencies and a specific master programme, which was not done before.

This research is useful for the AM programme, because the survey showed that most students are satisfied with internship and master thesis at company which was not presented in the NSE. Next to that, it is also useful for them because it also presented some points of attention regarding the internship. With these tips, the students would hopefully be more prepared for their internship.

It is useful for the fiels of Science Communication, as specially for engineering education, as it combines adaptability and adaptive expertise in the workplace with an engineering programme and yields a tool that may narrow the gap between programme and labour market. With this information, study programmes could find ways to add these competencies in their curriculum.

Next to adding more focus on adaptive competencies, Staff member 4 and the student interviewed for the course Mathematical Data Science, said that more focus on collaboration is useful. Graduates also mention in the survey and in the interview that doing projects was useful, so the programme could involve more project-based courses in their curriculum. This all will lead to more adaptive graduates, and also might narrow the gap even more.

In 2000, Pulakos et al. wrote an article about adaptive performance in the workplace. As told before, they found 8 adaptive dimensions of adaptive performance, which were tested among employees who need adaptability at their job. They found out that a job requires a specific set of adaptive competencies, which may be different for another job. These competencies were not examined in the field of engineering or education which was done in this master thesis. These competencies were used to find out how AM graduates could become more adaptive and what the programme could offer to the students. Next to that, adaptability was also used to investigate and narrow the gap between programme and labour market, which was not done before. Monteiro et al. (Monteiro et al., 2019) investigated the university-to-work transition and investigated whether career adaptability resources are different for before and after graduation and if there also is a difference between students who did or did not get a job. Although they did investigate the gap between programme and labour market, they did not try to narrow that gap.

9 Conclusion

This thesis was done to answer the following MQ:

How could the MSc Applied Mathematics programme at the TU Delft prepare the AM graduates for the start of their professional career by including adaptability in the curriculum?

We answer this question by first answering the sub questions.

1. How does the programme and other responsible departments prepare AM graduates for their professional career?

The programme offers a mandatory internship, which students could do as part of non-mathematics electives, or during their master thesis, or do both. The programme explained that students will encounter a culture shock when they enter the work environment, and by doing an internship this shock will be less intense. The reason for this is that the programme focusses much on the mathematical depth and working at a company focusses more on applying the knowledge and using mathematics as a tool and is not the goal. The programme does not offer preparation for the internship.

The programme also offers the course Mathematical Data Science, where students solve a problem for a company. Here, students have to communicate and collaborate with the industry as well as with fellow students, where they all deal with uncertain work situations as well as demonstrate interpersonal adaptability.

The study association prepares students by organizing lectures, events and company visits to learn more about the professional career. During these lectures, students learn more about soft skills, like negotiation, pitching, job application, but also information about CV.

Career & Counselling Services focusses on offering the right training to find the right job, enhance self-awareness and prepare students for job applications, next to, offering possibilities to meet with alumni and companies.

2. What barriers and facilitators do AM graduates encounter to adapt to activities in their job?

It is expected that after AM students graduate, they will have the following four adaptive competencies: *Dealing with uncertain and unpredictable work situations, Learning new work tasks, technologies and procedures, Solving Problems Creatively, and Demonstrating Interpersonal Adaptability*. The survey shows that almost all participants believe they have all these perceived competencies. For each adaptive competency, the graduates who were not adaptive had to share why this was the case (barriers), and the ones who were adaptive had to share what helped them to have this competency (facilitators). As there were not enough non-adaptive graduates, no hard conclusion could be made about the barriers. Table 32 presents the most chosen facilitators per adaptive competency.

The survey also shows that the programme does not offer enough courses where students could improve the following adaptive competencies: *Dealing with uncertain and unpredictable work situations, and Demonstrating Interpersonal Adaptability*.

Table 32 Facilitators of the four adaptive competencies Dealing with uncertain and unpredictable work situations, Learning new work tasks, technologies and procedures, Solving Problems Creatively, Demonstrating Interpersonal Adaptability for Applied Mathematics graduates. Same as Table 29

Dealing with uncertain and unpredictable work situations	Receiving Help
	Open to Change
Learning new work tasks, technologies and procedures	Doing Projects
	Having Freedom
	Collaborate with Others
Solving Problems Creatively	Doing Projects
	Having Freedom
Demonstrating Interpersonal Adaptability	Participate in social work situations
	Situation

3. How does the programme help students to learn to adapt to situations related to the professional career? What kind of courses do they offer to do so?

The programme says that the internship is a way to familiarize one with the labour market, and as graduates say they encounter adaptive situations at their current job, students will also encounter these at their internship. The course Mathematical Data Science, where students work on a project for a company, also prepares students for their professional career in a way, as they work a case for a company in a team.

4. What type of tool could help the programme prepare AM graduates to be adaptive in the first 3 years of their professional career?

An online tool was developed that prepares students for their internship as well as their professional career. In the online tool, students become aware about the adaptive situation's alumni encountered during their current job or internship, students will develop personal learning goals about these situations, which they will practice during their internship, and students will also reflect on these goals, and think about the implications of what they have learnt are for their professional career. This tool contributes to narrowing the gap between master programme and labour market, as it could develop more adaptive students, which will help students start their career more smoothly.

5. How does this tool contribute to graduates professional career preparation (with the focus on adaptability)?

This tool prepares students for their professional career as it makes them aware about the possible situations, they might encounter which are difficult or different from what they are used to. Interviewed graduates shared several adaptive situations which they bump into at their current job. This tool will create awareness among students, and by developing personal learning goals and practicing them at their internship, the students will improve

their adaptive competencies and become more adaptable. Being more adaptable will help them smoothen the transition from programme to labour market.

> *How could the MSc Applied Mathematics programme at the TU Delft prepare the AM graduates for the start of their professional career by including adaptability in the curriculum?*

The master programme Applied Mathematics at the TU Delft could prepare their students for their professional career by focussing more on two adaptive competencies: *Dealing with uncertain and unpredictable work situations,* and *Demonstrating Interpersonal Adaptability*. A possible way to do that, is to add an online preparation tool developed in this thesis. As told before, the tool aims to increase awareness on the adaptive situations the students might encounter at their internship or professional career. By developing and practicing personal learning goals linked to the two adaptive competencies, and reflecting on them, the students will improve these competencies. With these improvements, the students will become more adaptive, which will smoothen the transition from programme to labour market.

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Appendix

A. Interview Protocols (Dutch)

A1. Staff Member 1
- Wat voor soort professionals leidt de master programma applied mathematics op?
- Hoe verhoudt dat zich tot de arbeidsmarkt?
- Wat zoeken bedrijven voor soort wiskundigen?
- Hoe zorgt het onderwijs ervoor dat zulke wiskundigen ontstaan?
- Wat is uw interpretatie van de NSE?
- Heeft u misschien vragen die ik kan proberen te beantwoorden?

A1. Staff Member 2

- Stage procedure
    - Hoe vinden studenten een stage
    - Bij wie kunnen ze langs voor hulp
    - Wat moet er zoal praktisch geregeld worden? (contract)
    - Hoe lang lopen ze stage
- Taken tijdens stage
    - Wat zijn hun taken
    - Waar ligt de focus
    - Ervaren ze problemen
    - In welke situaties nemen ze contact met de begeleider op
- Assessment
    - Wanneer krijgen studenten een (on)voleonde
    - Wat moeten ze inleveren (aan stage en aan de TU)
        - Wat staat erin
        - Reflectie?
- Wat zijn de leerdoelen van zo'n stage
    - Waar ligt de focus
    - Waarom is het verplicht
    - Waarom is het noodzakelijk
- Waarom lage score NSE
    - Hoe komt dat
    - Wat voor soort begeleiding krijgen studenten
    - Hoe kan dit anders
- Algemeen
    - Wat missen de studenten
    - Waar denkt u dat het beter kan

A2. Staff Member 3

Type student/gerelateerd aan studie

- Wat voor student leiden jullie op?
- Hoe draagt de studie daarbij aan?
- Wat voor werk gaan de studenten na dde studie doen?
- Wat voor studenten zoeken bedrijven?
- Verschil met HBO studentne?
- Wat voor andere kenmerken hebben ze nodig om in de praktijk te kunnen werken?

Professionele ontwikkeling

- Is er ruimte voor persoonlijke ontwikkeling? Of reflectie?
- Studneten/context gebonden/praktijk

Studie

- Wat zijn de leerdoelen van de studie?

NSE/Reflectie

- Weinig begeleiding stage, wat is uw kijk?
- Hoe kan dit anders?
- NSE – lage score voorbereiding, hoe komt dat?
- Wat doet de studie hieraan?

Algemeen

- Wat missen de studenten?
  - Reflectie zegt communiceren en samenwerken
- Is er ruimte voor een aanbeveling?

A3. Graduates

Huidige werk

- Wat voor werk doe je?
  - Taken
  - Hoe wiskundig is dit?
- Is dat werk meer richting de toepassing of is het meer onderzoekend?
- Hoe lang doe je dit al?
- Hoe heb je dit gevonden?
- Vind je het leuk?

Vorige werk

- Heb je direct na je studie en voor je huidige werk een andere baan gehad? Zo ja, kan je hier wat over vertellen?
- Wat zijn je taken? Toepassing of onderzoek?
- Hoe lang heb je dat gedaan?
- Waarom ben je van werk gewisseld?

Aansluiting Studie

- Wat is voor jou de definitie van werkveld of arbeidsmarkt?

- Wat is voor jou het grootste verschil tussen wat je leert tijdens je werkt en tijdens je opleiding?
- Wat is beetje niet het verschil maar leer je juist bij beiden?
- Sluit dit aan op je studie?
    - Zo niet, wat is het grootste verschil?
    - Waarom heb je hiervoor gekozen?
    - Zou je weer iets wiskundig willen doen?
    - Hoe ben je hier terecht gekomen?
- Hoeveel wiskunde gebruik je daadwerkelijk?
    - Is het moeilijker of makkelijker?
- Welke skills heb je nodig om dit werk te doen wat je nog niet had toen je er aan begon?
- Wat voor soort soft skills heb je nodig om je werk uit te voeren?
- Wat zijn de uitdagingen?
- Krijg je hulp?
    - Zo ja van wie en hoe?
- Bied je werkgever traingen aan?
    - Zo ja wat voor trainingen?
    - Heb je zelf zo'n training gevolgd? Verplicht of vrijwillig?
    - Soft skills? Technische skills?

Toekomst

- Zou je nog ander werk willen doen?
    - Zo ja, toepassing of onderzoek?
    - Waarom wil je dat doen?
- Zou je dat bij een specifieke werkgever willen doen?
    - Zo ja, waarom en welke?

Stage gelopen

- Heb je stagegelopen?
- Wat waren je taken?
- Was het moeilijk of makkelijk?
- Was je voldoende voorbereid om het uitvoeren?
    - Zo niet, wat miste je?
- Makkelijk een stage gevonden?
    - Hoe heb je een stage gevonden?
- Wat heb je geleerd?
- Wat hoop je te leren?
- Wat viel tegen?
- Is er een verschil tussen je stage en je huidige werk?

Algemeen

- Wat vond je het waardevolst aan je studie?
- Wat vond je het leukst of minst leks?
- Wat kan verbeterd worden?
- Welke skills miste je toen je eerst begon met werken, die je nodig had en je niet vanuit de opleiding meekreeg?
- Welke skills zou je willen verbeteren of wil je leren?
    - Heb je deze skill tijdens je opleiding opgedaan?
    - Is dit soft skills of technische skills?

A3. Interview Teacher and Student for course Mathematical Data Science

Vragen over het vak

- Wat is het vak Mathematical Data Science?
- Wat is het hoofddoel van het vak?
  - Als de persoon zegt iets met het werk leven, vraag dan: weet de student dit? Is dit voor de student duidelijk?
- Waarom is het vak opgestart?
- Welke aspecten van het vak zijn voor de nieuw? (Dus waar de student nog niet eerder aan heeft gewerkt)
- Welke aspecten van het vak zijn het belangrijkst voor de professionele carrière van de student? Waarom?
- Vergt dit vak een andere manier van werken ten opzichte van wat de student bij andere vakken nodig heeft? De studenten doen meestal geen projecten voor een bedrijf?
- Wat vond je het waardevolst eraan? **(aan student, [dit] is voor mij belangrijk, maar hoe zie jij dit)**

Vragen over het vak gerelateerd aan de competenties

- Zijn er bepaalde onzekere of onvoorspelbare situaties waarin een student zich bevindt binnen het vak?
- Zijn er bepaalde onzekere situaties voor de docent tijdens het vak?
- Wat voor invloed heeft dit op de student zelf, de relatie met de docent en de samenwerking tussen de student binnen de groep?
- Wat doet de student om deze onzekerheid te overwinnen?
- Wordt er al gefocust op deze twee competenties binnen het vak?
  - Zo niet, hoe kan dit wel toegevoegd worden?
  - Zo wel, hoe?
- Wanneer wordt er samengewerkt?
- Hoe wordt er samengewerkt?

Vragen over toevoeging van de competenties en facilitators

- Hoe zouden we de student kunnen voorbereiden op die onzekere en onvoorspelbare situaties
- Hoe zouden we de student kunnen voorbereiden om in interpersoonlijke interacties zichzelf aan te passen?
- Is er ruimte voor een toevoeging in het vak?
- Heeft dit nut?
- Wat zijn belangrijke randvoorwaarden binnen het vak om zoiets toe te voegen?

B. Interview Examples

B1. Example staff member

How do they find an internship?

"There are different ways. We have a list of projects. So, some companies have positions and are looking for students. We put them on the internship site on brightspace." Students respond to that. There are short reports on brightspace. At the end of the internship, the students have to write a short report about the internship. This report is mainly for new students, who still need to do an internship and to help them find such an internship easier. Reports are about: I have been here, I had to do this subject, I liked it. Sometimes they say they found it practical. That stays within brightspace only for our own students. "Practice shows that it is often easy to get an internship. You don't have a lot of math students yet, compared to other subjects." They are in demand. Sometimes students don't manage to find it. The staff member […] can serve as a kind of mediator. "We want them to get to know a company inside." But such an internship is also allowed internally at TU Delft if it is an applied project.

Students are looking for an internship

The reasons for such an internship are different: how exactly does a company work inside, specifically in their field or outside, internship abroad or necessarily in Delft. "So the student has the lead and what he wants is important."

When will the student see you?

At the beginning of the internship. They have to send a proposal. The student wants to know in advance whether the internship is sufficient. Companies want a letter from the program that it earns credits and want it to contribute to the program.

How long do they do an internship?

Most do 18 points, three months. Companies want something longer. Sometimes a part-time job.

What do they do exactly? Research or internship (meeloopstage)?

Usually a small research project, for which the company usually has no time. Sometimes internship: several small projects. 90% is a project.

Does it connect to knowledge of the training?

"The practice is that the mathematics needed in the internship is generally modest. The practical problems that are mathematically not super difficult. That is also one of the reasons why we want the students to be familiar with professional practice. Because it's not that you have to solve it mathematically in the very best way, but you have to solve it in such a way that the company is satisfied with the result. Normally, the students go on an internship themselves, if it is difficult mathematically we add one of our own experts, but that is seldom the case. It hardly ever happens that the student needs mathematical help. Or that is already part of the company, then the expertise is there. Or the problem is not difficult in relative terms".

Where is the focus exactly? Applying mathematics in practice or gaining experience, working with people?

"Mathematics is a means and not an end. They have to solve a problem and they have to communicate with the problem solver, and they have to gain experience with how things are done in such a company". There used to be no internship and he indicates that sometimes it is a culture shock. During the training the students are focused on math knowledge and in business this is not always necessary, and they are not all interested in how to do it in the best way. They want to solve a problem. The main goal is to learn that mathematics is a means and not an end result.

Assessment, do they also look at what they have learned, e.g. did I learn to work together?

The students submit two types of reports: a small report for students who still need to do an internship to get a picture of what is going on, this is put on brightspace. In addition, a larger report and show what they have done and to show that they actually did 3 months, these are confidential (the project, literature, what did you do). They tell what they have learned.

What do they normally describe what they have learned?

That depends on the project. This is the company they are in and why they are interested in certain types of problems. They also read literature. Then problem definition, what did they do, conclusions, literature list.

Are there problems the students encounter?

Sometimes, it doesn't work between the student and the tutor. In general, students are happy with the help. They generally like it very much. They feel that their input is desired. They like to look inside the kitchen. "It rarely goes wrong."

Why do you need an internship?

"Because of that experience you have. If you look at our education, it's pretty mathematical in nature and quite a lot of theory as well. If you look at where the students end up, it's not at a math faculty. That's a fraction. [...] While for the most part it is while we are preparing ourselves well for it. We also have to prepare them well for a workplace outside mathematics. I think it's important myself."

How is assessment?

The internship is far too diverse, so they don't get a grade, but a pass or fail. In addition to the two reports, the company where the student did the internship also submits an assessment. That together is the basis. "The learning goal is mainly to gain experience with. So it always goes well, unless the tutor thinks the student was not present and did not do a good job.

In the Critical Reflection and NSE it says that students feel or feel little prepared for the internship, what makes you think that is?

Two reasons: an internship is a unique position and different in character, because the rest of the program is quite mathematical and goes into depth and an internship is totally different. "There is a bit of a culture shock, which we want to avoid when students have graduated".

Could that be avoided?

In the past, the students who did an internship had to give a presentation to the students who still had to do it, but it wasn't compulsory, so they didn't come. We did this to bring to light several internships and also the people who still had to do an internship to see what was going on. This would work if it was mandatory, but he finds it too complicated to organize. So, they stopped doing it.

In what period will they go on internship?

It's very variable and everyone plans it at their own moment.

Do you also have contact when they do a graduation internship?

He has no contact with students doing a graduation internship. They do have to show that they have done an external project. The supervisor has to check this himself or herself.

What kind of math students are the math graduate (e.g. SEC), i.e. the type of student?

"In mathematics, they are creative and enterprising. What they do have difficulty with is that in practice they have to think wider. So our students often have the feeling that we do the mathematical problems and the civil engineer has to solve the rest. But in practice it is often that the mathematician is also put into that role as project leader and then you also get a problem from practice, which is not formulated in terms of mathematical models and then you have to find out for yourself which mathematical models you can use for this. That's one level higher and our students have trouble with that".

How do you see that?

He has contact with students. Those modelling courses are an example of how the study tries to prepare a student for the difficulty mentioned above. Modelling and internship are important to him. The internships go remarkably well.

What are companies looking for in general?

For companies, mathematics is just mathematics. Sometimes there are differences in specific fields, but not very specific a type of student. They are looking for mathematics, econometrics, computer science. They can also find other types of students.

What are the students missing in general? What do students want to learn more about? For example, communication, multidisciplinary work?

Communication and multi-disciplinary work do not help them much. He does look up to civil engineering, for example, because with a thesis they work more as project leaders and with mathematicians the focus is on mathematics and they go deeper into it. But that problem is much smaller.

"I think that working together and interdisciplinarity and bringing the bigger picture together are important aspects. And I can well understand that they can learn a lot from that".

What kind of work are you doing currently?

I am currently doing a PhD.

How mathematical is this?

This is very mathematical

Why did you choose it, or how did you end up here?

Actually, because of my graduation. So, I always had the advantage that I was more interested in the theoretical side of mathematics. And I come from applied physics and then I switched to mathematics and because I didn't want to do a whole bachelor again, I could only go to Applied Mathematics. Because that was both in Delft, but I still followed so many theoretical subjects in the master's and then I finally joined my supervisor for my graduation project, which also touches a bit on theoretical physics. And I really liked that. And there are other subjects he was working on that I also found very interesting and in the end, he offered me a position.

You were already interested in theoretical mathematics and through your thesis you ended up there.

Because it just worked very well. And the subjects did fit in.

How long have you been doing this?

Six months

Do you like it?

Yes, so far I do.

What do you like about doing a PhD or work?

I am still very much in the beginning phase so I cannot say what it will be like at the end. I like it very much to learn new things each time and to understand better how things are connected. And in a very fundamental way.

Do you do besides pure research also other kinds of tasks?

Yes, sometimes I also have to help with education. That means answering questions during lectures.

Do you like that too?

Yes, I do. Less fun, though. It's in your contract that you have to do it.

Did you have another job immediately after your studies and before your current job?

I have a summer job. I took a little vacation for a month.

Did you do an internship during your studies?

Yes, I did an internship. At a company that mainly focuses on applying mathematics to problems that companies experience. It's between academia and industry. It was also founded by academics.

What were your tasks?

I had to find out whether a certain problem could be solved efficiently with reinformance learning so that it would work alongside similar problems.

How mathematical was that?

Reinforcement learning was mathematical, only I didn't have to go into great details of how it actually works, but rather applying it to a specific problem. In the end that boils down to programming and a little tuning of parameters. So quite mathematical. You need it to understand it, but it really was the application.

Was doing your internship easy or difficult, or harder than you expected?

I didn't really had expectations. I did it just to see if I like to work at a company. All went well.

Did you like that, because now you're doing something completely different. For example, why didn't you choose to go into industry?

First of all, I had the idea that you could do that later on, while the other way around is not always that easy. In addition, I also had the internal urge to continue learning. And I didn't really see myself living a life like that yet. It had become very predictable. Yes, I don't know. It just didn't really appeal to me. Although, I didn't like the content of it either, while the idea of what we're doing is a lot of fun. You're trying to understand intelligence there, Reinforcement Learning. However, in practice it's not fun at all. Only the idea of imitating intelligence is. However, in practice I found it a bit disappointing.

By disappointing, do you mean that you didn't use enough mathematics?

It became more of an engineer where you have to turn knobs and you don't really understand why it does or doesn't work. It had a very long feedback loop, so when something doesn't work you don't know if you made a mistake in your code or if you didn't train too long or if a parameter was just not right. And that was pretty frustrating.

Did you do that together with people or did you do that project on your own?

This project was alone. I was supervised, but it was on my own.

What did you find at the end?

At the end I found a little bit, you have different methods to try to deal with this and I had chosen one that was very obvious that it wasn't well suited for that specific problem and that maybe it would work with another method. And I also had an idea which one exactly.

At the end of your internship you still had to write a presentation or a report?

Yes, both.

Was your supervisor mathematical or from another background?

I think everyone there is quite mathematical. I don't know exactly where they studied, but it really is a company with mathematicians.

So, everyone has a background in mathematics, so to speak.

Yes, applied mathematics.

What did you learn mainly during your internship?

Both in terms of content and for myself I learned things. In terms of content: literally what I was working on, what reinforcement learning looks like and what it's like in practice. And yes, all details of that. And for myself: getting a picture of what it looks like at such a company and how working there is, how the culture there is, how I liked it. That's what I learned.

For what purpose did you go there for an internship?

I have already answered this a bit. I had several goals. I'm not sure I remember them all. One thing was to see if I liked the industry and I could then compare it to my graduation which would be more like a PhD. Another reason was that I was interested in Artificial Intelligence anyway and that I wanted to gain more experience in it and also to experience how it is. And also, to learn more from it in terms of content. So, I think especially those three goals.

What was disappointing?

How the work in AI looks like in practice was disappointing. And also, the atmosphere at the company itself was not very pleasant. It was really a bunch of mathematicians who come to work and after that they go home and apart from that it's not necessarily very pleasant or something. I also worked at another company and it was much nicer there. There you also had some very nice conversations with people.

So you missed that too?

Yes

Is that something you paid attention to when you started doing this work?

Well, I didn't intentionally pay attention to it, but it just stood out.

But is it just something you would take into account in the future that I want to do later?

Yes, absolutely. When looking for a company I'm definitely going to take into account the atmosphere there.

Is there a difference between your internship and current work and what is the biggest difference?

I don't know how to put that into words. It's just that what I'm doing now is much more theoretical. Actually, I was also kind of investigating how something can be solved with a certain method, only it was focused on the application.

Did you also do you master's thesis as an internship at a company?

No, my graduation project was at the university.

You just said that to be sure, you also chose to do your graduation project here because you wanted to know what it's like to do real research. And the application again, so to say.

I just wanted to get a clearer picture for myself of what I wanted to do after my studies.

Now I'm going a bit more into the connection between your studies and your work, because of course you do a PhD, that's clearer, so to speak, but I've interviewed different people and different definitions have come out for 'preparation for the job market'. There are four definitions: (1) There is no clear picture of what is possible after taking the master's, (2) students do not have the right skills to do the job, (3) students are not used to the work atmosphere, the 9 to 5 working life, and (4) students are not sufficiently prepared for applying for a job.

Actually, I think everything you mention is important, both knowing what is there and the skills needed to do it. Also, content and everything that comes with it, so not only content.

Students are not used to the work environment, working from 9 to 5.

I wouldn't do that at university. I wouldn't know how they would prepare you for that.

It's more of that mathematics is not the end but more the means.

Yes, it is.

So that's what it mainly means and that's the preparation for applying for a job. And do you feel that you are sufficiently prepared for the job market for your current job?

Should I make a distinction between what I think the study should have prepared me for or not?

What they have done.

Should I include everything that has nothing to do with the study in my preparation?

I also have a question of yes what you learned during your studies; what skills you need to do the work you didn't have when you started. So more of what you did not learn during your work.

So that will come later?

Yes, what do you think of the four definitions and which one is most appropriate for you?

I would say that applying for a job and how to do it is not the job of your education. But I still think it is important for preparation, but TU Delft does not have to do that. They could offer a voluntary profession course or something like that. It does not have to be in the master's in Applied Mathematics. And there was another one.

Working environment not used, not the right skills?

The nine to five. The other two I believe in.

So that there is no good picture was possible and the right skills to do the job?

Yes, I like those two.

... Where the study has a role. What is for you the biggest difference between what you learn in your work and during your education? What skills do you need to do this work that you didn't have when you started work, what the course didn't teach you?

I think networking. And that is actually the most important thing.

And that's what you need at your current job?

I think it's unofficially very important. A lot of what you do is in collaboration with people, so you have to be considered with the right people. Just build a network. But then with certain people in your field that you would like to get in touch with.

To work with later?

Actually, working with people closer together just when there is a postdoc working in a similar area. They can also appeal to you. Keep it to networking.

What soft skills do you need to carry out this work?

Presenting. Presenting yourself and presenting the content, I would say. Of course, communicating math in general. I think that is the most important thing and what I just said networking.

For example, do you have to communicate, communicate the mathematics to an audience who doesn't understand it or to the community?

That will be important, but not yet for me. It becomes especially important if you want to apply for funds or have to raise money. I can imagine that it is important then. For my supervisor it is important.

What are your biggest challenges? In general, so what do you come across during your work?

I don't really have that clear to myself yet. Yes, I think it's more substantive than I'd say, but I still have a lot to learn because I went from applied master's to more theoretical PhD, so I still have a backlog and catching up is a big challenge. So, I think that.

Are there soft skills you would like to improve?

Basically, I would like to improve any soft skills. What in itself would be nice to learn is to become better in teaching. But that's not really essential or anything but it would be useful because if I have to teach, it would be useful to know a bit about it. I also just have to answer some questions and then you might not really need it, but I think it would be a good idea to learn a bit more from it.

What is the biggest difference between your education and your work?

I would say here that with education, it's both mathematics, of course. There is someone who knew the answer who can guide you there and now it's not. Even my tutor doesn't know how things work.

So, you don't know where you're going, you don't have an answer.

You only have a question and you don't even know if that question has a good answer.

How do you deal with that? It is of course a process, so you don't have the answer within a day or a week?

Indeed, there are several things. First of all, you have to start trying to answer the right question, because you can start trying to solve an enormously difficult question. That is not clever, and you can also do something very easy. I rely on the intuition of my mentor to do that. He has much more experience in this. And furthermore, how to solve that. I just do my best. I start thinking and looking and then I have a conversation with my supervisor every week. That he can steer me in a better direction. He keeps me a bit on track.

I've just asked what's the difference, but what's a match?

Mathematical content.

Does your study tie in with your work?

Yes, in so far. Almost as I just said, I've gone more in a theoretical direction and for that I would have been more of a theoretical study and also a little more my own choice.

How do you get to that level because you feel a bit behind but how do you make sure you don't?

You always learn the things you need most urgently and then over time the gaps get smaller and smaller, but of course you do the things I need right away first.

Don't you for example follow courses?

No, but I could do that. I couldn't really follow courses that I thought were worth the time, because it takes a lot more time to do all those assignments and exams than just reading about them in the book.

For example, you indicate that you will get help from your supervisor and that he will offer you help on a weekly basis. What kind of help is that? Is it more content or I will look at this or is it also more about how do you feel and is everything going well?

It really is more the first thing. But if I'm interested in the second, I think that could be possible, only I don't think I radiate that. I keep it more professional and not personal.

[part removed, due to personal content]

Who do you have the most contact with at work?

My supervisor. It's a bit different in corona time now, because normally I don't, and I have more contact with the PhD'er who is sitting next to me. I talk a lot about that and then I ask small questions, but I can't do that now.

Do you still talk to that colleague?

Yes, we now have a sort of seminar-like thing once a week where we all talk about a certain subject at the same time and then talk about it. And then we just chill out.

Does your employer also offer training courses for you as an employee or for you as a PhD?

Yes, your employer does. In fact, I am obliged to do them. Here you have something called Graduate School of Education where you have to earn points within different categories.

What kind of training could you do?

A lot of different ones. There are different categories, so one is really substantive, then you could take master's courses for example master math. They call them transferrable skills and these are more soft skills things like time management is one of them, I think teaching is another. Presenting in different contexts, also to non-mathematicians or mathematicians. And also teaching, that kind of things. That is a bit what I can think of now.

Have you already followed a training?

Yes. A number of them did not really have a useful name, they are general for the PhD process and one I did was time management. In general, a lot of these things did not excite me very much and I can win them back in time, you know. It was useful in itself. You learned tricks to handle your time better.

What kind of trainings are you going to follow in the future?

I have an idea anyway, but not very much. I want to do something about presentation anyway. I would have done it even if corona hadn't been there.

Are these trainings more soft skills or technical or substantive?

Both.

Would you like to do other work after your PhD that doesn't resemble what you're doing now?

I'm certainly open to it. I don't know if I'm really going to want it or not, it all depends on how I'm going to do it over the next four years, how I like it. And whether I like it after that. But, yeah, sure.

What kind of work would you like to do, because for example you indicated that you regretted that your internship was a bit less substantive and less in-depth, how would you see that in the future?

I find that a difficult question. I don't know if there actually exists what would be the ideal employer for me. I have the feeling that there isn't. So I would still like to have substantive work, but also a pleasant atmosphere and that you might have a real application or at least the idea that you are contributing to something that you find important and that you also have the idea that it is useful.

That you also make an impact?

I think that's a pretty big word. That you at least believe it is useful. I think there are a lot of people who do a job who don't think their work is useful at all.

You indicate that you don't know what you're looking for exists. I have the feeling that it does exist that you can go into business and mathematics, but how come you have that idea?

Because I haven't found it yet. Everything I see around me; I don't see myself working there. Say you all have consultancy and banks and I know a lot of random companies that make printers or so I haven't yet found something that excites me.

Are you getting excited about your PhD now?

Yes, I am, but I'm still open to do something else.

But it just depends on how you feel after those four years, because you still might like it after those four years?

Yes, but there are other things that come with it. A PhD: if you want to continue working or studying with that, you soon have to move between different countries very often, because then you're going to do a postdoc because that's, usually you can't find that in the Netherlands. And that's for two years and it's very difficult to find a new position every time, so actually everyone I speak to who has lived in three countries for a long time in the academic world and I think that's quite a serious sacrifice because you can't build a social life. So really good friends that you have known for five ten years and so you can never find new ones every time.

So that does play a role for your future plans?

Yes, absolutely, because at the end of the day we are social beings, you have to take that into account.

Yes, that's right. Now some general questions. What did you find most valuable about your study

I kind of think that I am trained to think in a certain way.

Analytical thinking?

Among other things, but perhaps not only that. I just can't put it right, I haven't found the words yet.

It's not just analytical, then what do you need that capacity to think in what tasks you perform?

Maybe it is also a picture of how mathematics or physics comes back in all applications seen all over the world and how that is related to mathematics and physics.

Also be able to see the big picture about a certain aspect and link it back to mathematics and physics. Or is that too short. Do you have an example?

Then I have to think for a moment. For mathematics that you have a picture of how all algorithms in the application can be found in business and then you can think of yes I know a lot of optimization things or something that hopefully are relevant as well. But for physics also just more in real life you have an MRI-scanner how that works a bit how you get a quick picture of how the information is processed there, not exactly you may not know the details

you should find out, but you have a bit of a feeling for that. But I think it comes more from the physics [education] I did. Not so much from mathematics, because I've never seen that before.

What did you like most about your education?

Everything around it actually, just the student life itself. If that is also an answer. I also think that's one of the other things I've learned a lot from your interaction with all the people around you who think differently from you or you just learn a lot from that.

During your education you deal a lot with mathematicians only, but in business you should of course deal with people from the business side, do you have experience in that as well?

In my first year in physics I had a subject in which you had to do something together with managers, first year management, second year management, so that's what I did. That was quite difficult. The idea was that a lot of technical people hated managers and that the communication and collaboration between these two groups went very badly. But the effect of this was that it started at a much earlier stage.

It's not an effect at all what they wanted, which was to improve the collaboration, that didn't happen?

In my group it was quite okay. I still had chill people, but a lot of people around me were irritated all the time.

What were they irritated about then?

I don't know that anymore. Further if I have experience with that. Not necessarily that I have worked with them a lot myself, but just that I have contact with people who do totally different things.

Dealing with or thinking about things?

Yes, or thinking about things. They are just busy with completely different things and it is not always so logical and rational, and it is not entirely clear either that one is better than the other.

What did you like the least about your studies?

Maybe a number of subjects that just did not interest me. There was an ethics course and I liked it, and there was another course.

Mathematical modeling in society?

It could be that it was.

That was with the fact that you had to present from time to time and not the teacher.

Yes, something that some groups had to present, which I didn't like. And yes, you had to choose from a number of other subjects and for example discrete optimization.

Yes, exactly, because that subject MM was of course meant to teach students how mathematical models are used in business. Why didn't you like that, for example?

It is indeed the MM box, but I don't really know what we actually did there. If I'm being very honest. I really felt at the time that it was a waste of time that I really didn't learn anything. I really don't even remember what I learned.

It had no impact. It felt useless to you?

I don't remember what we did. I can't remember.

Now I have a general question, because you did the track analysis and I think very few students do that anyway. And I for example CSE or Optimization those courses that are a bit more applicable anyway so what kind of work could a person who has done your specialization do.

I think that if you really start looking for work with only the knowledge of analysis, you won't get very far, except at some banks because analysis and probability can be quite close together. If I were to look for work, I would show that I can do more than just that.

Would you be able to do work that is not at all related to mathematics or would you like to keep doing mathematics or physics?

Yes, in the short term I would, but in the long term I might do something completely different. It could play a less important role.

C. Quotes and Codes of Facilitators from interviews with graduates in Dutch

Table 33 Quotes and Code of Facilitators from interviews with graduates in Dutch

	Codes	Quotes	Alumni
Doing Projects	BEP draagt bij aan hoe je project aanpakt	"Met name door je bacheloreindproject, heb je al heel wat geschreven en weet je een beetje hoe je moet documenteren en hoe je een project aanpakt"	A3
	Het hebben van programmeerskills	"Het feit dat programmeren in vakken, in R, Python in verschillende talen."	A3
		"[…] Ook betere programmeerskills"	A1
	Vakken met project waardevol	"Dat was het eerste vak waar je dan ook zo'n grote opdracht krijgt dat het dan best wel, dan lijkt het op iets serieus. En voor de rest krijg je toch wel van die tor example, die eigenlijk te goed in elkaar zitten waardoor je nergens tegen aan loopt. [en zo gaat het natuurlijk niet] nee het is nooit zo mooi."	A4
	Project met ander vakgebied samengewerkt	"[…] is er een vak dat samen met Rotterdam school of management wordt gegeven, dan moeten we samenwerken met van die business mensen. Iedereen vond het echt verschrikkelijk, maar eigenlijk leer je er veel van. Want je moet samenwerken met mensen met wie ik nu ook samenwerk, die niks snappen van wiskunde, maar ook hun eigen manier van documenten schrijven hebben. Het is een heel ander vakgebied, dat komt allemaal samen in het bedrijfsleven. Dus dat is echt heel belangrijk dat je dat kan. "	A3
	Stage doen is aanrader	"Ik zou sowieso iedereen verplichten om een stage te doen."	A3
		"[…] dat is echt goed. Dat is nodig. Je merkt ook meteen de mensen die binnenkomen die dat niet hebben gedaan, die zijn gewoon anders. Dat zie je meteen."	A3
	Praktische opdrachten doen voor bedrijf was leuk	" Het feit dat programmeren in vakken, in R, in Python in verschillende talen. Dat is ook handig. En de bachelor (TN) […] is er een vak dat samen met Rotterdam school of management wordt gegeven, dan moeten we samenwerken met van die business mensen. Iedereen vond het echt verschrikkelijk, maar eigenlijk leer je er veel van. Want je moet samenwerken met mensen met wie ik nu ook samenwerk, die niks snappen van wiskunde, maar ook hun eigen manier van documenten schrijven hebben. Het is een heel ander vakgebied, dat komt allemaal samen in het bedrijfsleven. Dus dat is echt heel belangrijk dat je dat kan. "	A3

	Codes	Quotes	Alumni
Receiving Help	Hulp krijgen	"ja en als trainee krijg je heel veel coaching. Dan kun je dan met coaches bespreken hoe je daarmee omgaat."	A3
	Hulp van collega's	"heb ik meer contact met PhD'ers die naast mij zit. Daar praat ik over best veel en dan stel ik kleine vraagjes, maar nu kan dat niet." (corona)	A5
	Hulp van supervisor	"de tijdsdruk wordt vaak opgelost door de managers die een duidelijke planning maken."	A2
		"in het begin hadden we wekelijks een meeting. En dan kan je prima je vragen stellen en dan heb je iets om naar toe te werken."	A4
		"[ja precies. Je geeft bijvoorbeeld aan dat je hulp krijgt van je begeleider en dat hij je wekelijks hulp biedt en wat voor hulp is dat is dat meer inhoudelijk van okay ik zal hiernaar kijken daarnaar kijken of is het ook van hoe voel je je gaat alles goed] nee het is echt meer het eerste. Maar als ik interesse hebben in het tweede, ik denk wel dat dat mogelijk zou kunnen zijn alleen straal ik dat niet uit volgens mij. Ik houd het meer professioneel en niet persoonlijk."	A5
		"Daarop vertrouw ik op de intuitie van mijn begeleider. Hij heeft veel meer ervaring daarin. En verder ja hoe je dat dan oplost ik doe gewoon mijn best ik ga nadenken en kijken en dan heb ik elke week een gesprek met mijn begeleider. Dat die mij een betere kant op kan sturen. Hij houdt mij een beetje op het spoor zeg maar. "	A5
	Duidelijke planning door managers	"de tijdsdruk wordt vaak opgelost door de managers die een duidelijke planning maken."	A2
	Duidelijk communiceren	"Het is voornamelijk veel en duidelijk communiceren wat er gebeurt en hoe het ervoor staat"	A2

	Codes	Quote	Interviewee
Training	mogelijkheid om training te volgen op werk	"Ik heb gelukkig in mijn traineeship communicatietraining gevolgd."	A3
		"management drives training"	A3
		"communicatie skills, advisory skills, een soort consultancy skills. Presentatie skills. En we zijn nu bezig met een banking simulation game, waarbij je een simulatie van vijf dagen moet je een bank onderhouden, de content, de inhoud. Dan leer je hoe banking werkt eigenlijk."	A3
		"zeker, meerdere trainingen per jaar worden er georganiseerd (intern). En verder kunnen we vragen om extern een training te volgen als dit specifiek nodig is om bepaalde werkzaamheden te doen."	A2
		"Die vakken op zich is dat wel een training. Er is dan ook wel iets van een, hoe heet dat, dan kun je ook die presentatie skills en schrijf skills dat kun je dan doen."	A4
		"ja sterker nog ik moet ze verplicht doen. […] Er zijn verschillende categorieën, dus eentje is echt inhoudelijk, dan zou je vakken kunnen volgen master vakken bijvoorbeeld mastermath ofzo. Dat noemen ze transferrable skills en dat zijn meer soft skills achtige dingen, time mangement is er een, lesgeven is er volgens mij ook een. Presenteren in verschillende contexten, dus ook naar niet wiskundigen of juist wel wiskundigen."	A5
		"voor mij bijvoorbeeld SQL had ik nog nooit gedaan in mijn master. Dus dan moest ik dat in een weekje even bijleren. Dat geld voor alle databases. Elk bedrijf gebruikt dat."	A3
Networking	Netwerken	"netwerken. En dat is eigenlijk het belangrijkste [en dat heb je nodig op je huidige baan] ja volgens mij is dat onofficieel enorm belangrijk [en waarom] naja veel van wat je doet is in samenwerking met mensen dus dan moet je in aanmerking komen met de juiste personen. Gewoon netwerk opbouwen"	A5

D. Quotes and Codes of Barriers from interviews with graduates

Table 34 Quotes and Code of Barriers from interviews with graduates in Dutch

	Codes	Quotes	Interviewee
Corporate culture	Bedrijfscultuur niet leuk	"ik paste daar niet echt bij"	A3
		"het bedrijf was ook ruk"	A4
		"en ook sfeer op het bedrijf zelf het was niet echt gezellig"	A5
Not being able to ask questions	Durfde niet goed vragen te stellen want dat betekende verlies voor het bedrijf	"dus als je een vraag stelt dan heb je het verlies voor het bedrijf geleden, dat gevoel kreeg ik wel enorm."	A3
Wanting to be transparent	moeite niet transparant zijn	"nee het spreekt wel een beetje in tegen je natuur. Het kost wel een beetje moeite. Nu na een jaar kan ik het wel. Ook nog steeds, zie ik het nog steeds als mijn taak in het team om hard te zijn, eerlijk te zijn van jongens waarom zijn we niet gewoon transparant over dingen."	A3

Codes	Quotes	Interviewee
Weinig tot geen wiskunde	"Weinig tot niets, hooguit een klein beetje statistische analyse"	A2
	"niet zo wiskundig. Het is een wiskundig model, maar gegeven mijn kennis, vind ik het nergens op slaan."	A3
	"je mist je wiskunde achtergrond wel een beetje"	A3
	"dat vind ik wel jammer. Omdat ik meer kan en je loopt aan tegen het feit als wiskundige een heel moeilijk model kan bouwen, maar vervolgens moet je het nog steeds uitleggen aan managers die economie hebben gedaan of business, die helemaal geen wiskunde achtergrond heb en je gaat zoveel versimpelen dat in ieder geval het model een beetje uitlegbaar, dan weet iedereen een beetje waar het over gaat."	A3
wiskunde niet het doel	"het boeide ze helemaal niet hoe zo'n [Artificial Intelligence methode] werkte."	A2
	"[merkte je toen soms ook al dat het niet perse ging on wiskunde ging maar om wat je laat zien] ja dat vond ik daar echt hopeloos."	A2
	"Alhoewel inhoudelijk vond ik het ook niet heel leuk daar, terwijl het idee waar we mee bezig zijn is wel heel leuk. Zeg maar je bent daar bezig met proberen intelligentie te snappen [Artificial Intelligence methode] alleen in de praktijk is het helemaal niet leuk om te doen, alleen het idee om intelligentie na te bootsen wel. Alleen in de praktijk vond ik het een beetje tegenvallen"	A5
	"naja het [Artificial Intelligence methode] dat was wel op zich wiskunde alleen hoefde ik niet helemaal in te gaan hoe het precies werkt maar meer het toe te passen op het specifieke probleem."	A5
meer behoefte aan wiskunde	"ik zou iets meer wiskunde willen, maar in voornaamste project is er dus heel weinig. In andere project zit iets meer wiskunde, en dan is het best wel leuker om daar iets in te verdiepen, dus af en toe mag je eventjes."	A3

(Vertical label, left margin:) **Not using all their deep mathematical knowledge**

E. Operationalization Table

Table 35 Operationalization Table for Survey

Main Concept	Conceptual Definition (Pulakos et al., 2000, p. 617)	Related Variables	Operationalization
Adaptability	"Taking effective action when necessary without having to know the total picture or have all the facts at hand: readily and easily changing gears in response to unpredictable or unexpected events and circumstances; effectively adjusting plans, goals, actions, or priorities to deal with changing situations; imposing structure for self and others that provide as much focus as possible in dynamic situations: not needing things to be black and white; refusing to be paralyzed by uncertainty or ambiguity."	Dealing with uncertain and unpredictable work situations	AM graduates are asked to rate 8 statements on a 4-point Likert-scale to what extent do they have this competency (availability) and if it relates to their job (relativeness)
	"Demonstrating enthusiasm lor learning new approaches and technologies for conducting work doing what is necessary to keep knowledge and skills current; quickly and proficiently learning new methods or how to perform previously unlearned tasks; adjusting to new work processes and procedures; anticipating changes in the work demands and searching for and participating in assignments or training that will prepare self for these changes; taking action to improve work performance deficiencies"	Learning work tasks, technologies and procedures	AM graduates are asked to rate 5 statements on a 4-point Likert-scale to what extent do they have this competency (availability) and if it relates to their job (relativeness)
	"Employing unique types of analyses and generating new innovative ideas in complex areas; turning problems upside-down and inside-out to find fresh, new approaches; integrating seemingly unrelated information and developing creative solutions; entertaining wide-ranging possibilities others may miss, thinking outside the given parameters to see if there is a more effective approach; developing innovative methods of obtaining or using resources when insufficient resources are available to do the job. "	Solving Problems Creatively	AM graduates are asked to rate 4 statements on a 4-point Likert-scale to what extent do they have this competency (availability) and if it relates to their job (relativeness)
	"Being flexible and open-minded when dealing with others; listening to and considering others' viewpoints and opinions and altering own opinion when it is appropriate to do so; being open and accepting of negative or developmental feedback regarding work; working well and developing effective relationships with highly diverse personalities; demonstrating keen insight of others' behaviour and tailoring own behaviour to persuade, influence, or work more effectively with them."	Demonstrating Interpersonal Adaptability	AM graduates are asked to rate 5 statements on a 4-point Likert-scale to what extent do they have this competency (availability) and if it relates to their job (relativeness)

F. List of Barriers & Facilitators

Table 36 Facilitators and Barriers found from literature

	Dealing with uncertain and Unpredictable work situations	Learning work tasks, technologies and procedures	Solving Problems Creatively	Demonstrating Interpersonal Adaptability
Barriers	Not knowing (extra) Not being able to ask questions	Not Having Freedom Not participate in work situations Not participating in formal learning opportunities	Not being able to ask questions Not use all knowledge Not being transparent Not having freedom Not necessary Having a lot of tasks Not knowing Not having the right resources Situation Self-reflection	Corporate Culture Situation Not being in social situations Measure of fit
Facilitators	Network Help Feedback Open to change	Doing projects Help Network Training Do new challenges Participate in work situations Collaborate with others Freedom	Recognize Doing projects Resources Self-reflection Freedom	Doing projects Participate in social work situations Situation Measure of fit

G. Survey Results

G1. Survey Participants

Table 37 Number of survey responses per section, together with the number of respondents who quit

Section	Subsection	Questions/Statements	Reactions	Quit
Intro		Agree/Not Agree	40	
Adaptability	Dealing with Uncertain and Unpredictable Work situations	Statements	33	7
		Subsequent questions	31	2
	Learning new Work Tasks, Technologies and Procedures	Statements	28	3
		Subsequent questions	28	0
	Solving Problems Creatively	Statements	28	0
		Subsequent questions	27	1
	Demonstrating Interpersonal Adaptability	Statements	25	2
		Subsequent questions	24	1
Education			24	0
Current Job			24	0
Total			24	16

G2. Adaptability Results

Dealing with uncertain and unpredictable work situations

Table 38 Results of the question 'Is dealing with uncertain and unpredictable work situations part of your current job?'

Is dealing with uncertain and unpredictable work situations part of your current job?			
Yes	No	Total	Missing
23	10	33	0

Table 39 Results of the questions if the programme taught students to deal with uncertain and unpredictable work situations and if the programme was responsible to do so.

	Yes	No	Total	Missing*
Did the study programme teach you to deal with uncertain and unpredictable work situations?	6	25	31	2
Was the study programme responsible to teach you to deal with uncertain and unpredictable work situations?	5	26	31	2

* One participant did not have the perceived competency fully yet, and one quit the survey after rating the statements of this competency.

Average below or equal to three

The participant who scored below three got different questions than the ones who scored above three. Firstly, the participant agreed with not being able to deal with uncertain and unpredictable work situations. Then, the graduate was asked to choose from a set of possibilities to explain what the reason could be that the graduate does not have this perceived competency yet. The participant said, *'I like to feel safe: being in control, understanding the surroundings.'* So, the respondent added another possible barrier of dealing with uncertain situations. However, as the participant is the only one who mentions this, no conclusion could be made if it is a barrier or not.

Afterwards, the participant had to think what he/she/they need to increase or improve this competency. The participant chose 'more open to change'. Lastly, the participant does not believe the programme was responsible to teach him to deal with such kind of situations.

Learning new work tasks, technologies and procedures

Table 40 Results of the question 'Do you need to learn new work tasks, technologies, and procedures to do your job properly'

Do you need to learn new work tasks, technologies, and procedures to do your job properly?			
Yes	No	Total	Missing*
26	2	28	5

* Five participants ended the survey previously.

Table 41 Results of alumni if the study programme taught them to learn new work tasks, technologies and procedures and if they were responsible to do so.

	Yes	No	Total	Missing
Did the study programme teach you how to learn new work tasks, technologies and procedures?	20	8	28	5
Was the study programme responsible to teach you to learn new work tasks, technologies and procedures?	23	5	28	5

No students had an average below three.

Solving problems creatively

Table 42 Results of the question 'Do you need to solve problems creatively in your job?'

Do you need to solve problems creatively in your job?			
Yes	No	Total	Missing*
24	4	28	5

* Five participants ended the survey before reaching this question.

Table 43 Results of alumni if the study programme taught them to solve problems creatively and if they were responsible for it answered by participants with an average below or equal to three or above three.

	Yes	No	Total	Missing*
Did the study programme teach you to solve problems creatively?	16	6	22	11
Was the study programme responsible to teach you to solve problems creatively?*	18	6	27	6**

Average below or equal to three

For some reason, the only two participants with an average of 3.2 were also processed as 'not having' this perceived competency. This only happened for this competency. For this reason, we analysed the data in two ways: in case 1 we analysed the data with an average below or equal to three and we analysed the data with an average below 3.2 in case 2

Table 44 Results of the question 'Based on your answers, you are not fully able to solve problems creatively'

Based on your answers, you are not fully able to solve problems creatively				
	Agree	Not Agree	Total	Missing
Case 1	3	0	3	0
Case 2	4	1	5	0

Table 44 presents the number of students who agree or disagree with the result of not being able to solve problems creatively. As shown in Case 1, the three students all agree, but in Case 2, one student does not agree.

We also analysed if these participants need this competency in their job, which is presented in the table below:

Do you need to solve problems creatively in your job?		
	Case 1	Case 2
Yes	1	3
No	2	2

No hard conclusions could be made about Table 45.

Table 46 presents what participants believe the reason is why they are not fully able to solve problems creatively yet. No real hard conclusions could also be made, due to the number of students is too low.

Based on your answers, you are not fully able to solve problems creatively. What do you think the reason for this is?	Case 1	Case 2
I am not able to ask questions, which I need to solve problems creatively		2
I do not use all of my mathematical knowledge, which limits me to solve problems creatively	1	2
It is not necessary to solve problems creatively	1	2
I do not know how to solve problems creatively	2	3
I do not know when to solve problems creatively		1

Table 47 Results of the question 'Based on your answers, you are not fully able to solve problems creatively. What do you need to increase or improve this?'

Based on your answers, you are not fully able to solve problems creatively. What do you need to increase or improve this?		
	Case 1	Case 2
I would like to receive more information on how to solve problems creatively	1	2
I would like to receive help from colleagues, coaches or managers more often	1	1
I would like to have more freedom		1
I would like to have more resources, such as technologies, equipment, and help	1	1
I would like to be part of projects where I could learn how to solve problems creatively	1	2
Other		1

Table 47 presents what participants say they need to increase or improve this competency. Again, no hard conclusions could be made due to the number of participants. In Case 2, one participant said, 'I would have to feel more confident, which is possible in a safer environment.'

Table 48 Results of the questions if the programme was responsible to teach you to solve problems creatively?

In your opinion, was it the responsibility of the programme to teach you how to solve problems creatively?				
	Yes	No	Total	Missing
Case 1	3	0	3	0
Case 2	4	1	5	0

Opinions vary when it comes to the programme being or not being responsible to teach students this competency.

Demonstrating interpersonal adaptability

Table 49 Results of the question 'Do you need to demonstrate interpersonal adaptability to properly carry out your job?'

Do you need to demonstrate interpersonal adaptability to properly carry out your job?			
Yes	No	Total	Missing*
21	4	25	8

Table 50 Results of alumni if the study programme taught them to demonstrate interpersonal adaptability and if they were responsible for it answered by participants with an average below or equal to three or above three.

	Yes	No	Total	Missing**
Did the study programme teach you to demonstrate interpersonal adaptability?	6	16	22	11
*Was the study programme responsible to teach you to demonstrate interpersonal adaptability?**	9	15	24	9

Average below or equal to three

In total 2 participants had an average below or equal to three, and all of them agreed that this competency is not fully theirs yet. Table 51 presents what participants think the reason could be that they do not fully have this perceived competency yet. However, due to the low number of participants in this category, no hard conclusions could be made.

Table 51 Results of the question 'Based on your answers, you are not fully able to learn new work tasks, technologies and procedures. What do you think the reason for this is'

Based on your answers, you are not fully able to learn new work tasks, technologies and procedures. What do you think the reason for this is?		
I do not enjoy the corporate culture, which hinders me to change my behaviour	I do not have to be in social or interpersonal interactions a lot. I work mostly alone.	I do not know which skills in social interactions to use to demonstrate interpersonal adaptability
1	1	1

It is also impossible to make a conclusion of what students may need to increase or improve this competency, due to the low number of respondents.

Based on your answers, you are not fully able to learn new work tasks, technologies and procedures. What do you need to improve this?	
I would like to social interact with my colleagues, coaches or managers more often	I would like to be part of projects to learn how to demonstrate interpersonal adaptability
1	1

Next to that, one student believed the study programme was responsible to teach them to demonstrate interpersonal adaptability (1 out of 2) and one student believed they were not (1 out of 2).

G3. Education

This section presents the results of the participants educational background as well as their satisfaction about the programme, doing an external internship and about doing a master thesis at a company.

Bachelor's Degree

Most participants who finished the survey did their bachelor at the TU Delft and followed the Applied Mathematics bachelor's programme. Two students did the double bachelor's degree Applied Mathematics and Applied Physics. Most of the students also studies at the TU Delft (20), and one student did not mention at which university he/she/they obtained the degree. Nine students did not complete the survey.

Table 53 Participants educational background

Bachelor Technische Wiskunde (TU Delft)		14	
Bachelor Technische Natuurkunde (TU Delft)		2	
Other	Bachelor Bouwkunde (TU Delft)	1	8
	Bachelor Mathematics (Nazarbayev University)	1	
	Bachelor Physics (Eotvos Lorand University)	1	
	Bachelor Technology Policy and Management (TU Delft)	1	
	Both Technische Wiskunde and Technische Natuurkunde (TU Delft)	2	
	Civil Engineering	1	
	Grado en Matemáticas (Madrid Complutemse University)	1	
Missing		9	

Master's degree

The table below presents the month and year in which the participants received their master's degree. As shown, one participant mentioned November 2020, which is in the future. Next to that, one participant received their degree in September, and the survey was sent out in October.

Table 54 Month and Year participants obtained their master's degree

	Month	Number of participants	Total per year
2014	June	1	1
2017	July	1	1
2018*	June	1	5
	July	1	
	September	3	
2019	March	2	14
	June	1	
	July	2	
	August	2	
	September	3	
	October	1	
	November	1	
	December	2	
2020	July	1	3
	September	1	
	November	1	
Total	24		
Missing	9		

* One participant wrote 208, which was probably a mistake. As participants between who got their masters' degree between 2017 and 2020, 208 is 2018.

The study programme Applied Mathematics has five specialisations, which are mentioned in Table 55. Most of the participants followed the Stochastics track (8), and after that Financial Engineering (5). One student did a double degree with Physics.

Table 55 Distribution of the participants' specialisations choices

Stochastics	8
Analysis	3
Computational Science and Engineering	4
Financial Engineering	5
Optimization	3
Other	1
Total	24
Missing	9

Education – Conclusion

This subsection described the participant's educational background. They were asked which bachelor's degree they finished and when they finished their master's degree. Next to that, we also asked which specialisation they did.

Most participants did a bachelor's degree at the TU Delft, and most participants got their degree in 2019. Next to that, most students followed the Stochastics specialisation, followed by Financial Engineering.

G4. Current Job

At last, the participants were asked to share some information about their current job. Firstly, we asked them what type of job they do. The programme explained during interviews that most graduates choose between doing a research-based job or a function more on the applied side of mathematics. Next to that, some graduates also start their career in teaching. For this reason, we would like to know what type of job they do.

After asking about the type of job they do, we asked the participants when they started their current job, and afterwards we asked them to choose which tasks they do at the moment and the level of mathematics they use at their job. Lastly, we also asked if the amount of mathematics they use at the moment was the level they expected or not.

This section thus discussed the participant's current job.

Type of Job

Most students do a research of applied job, as shown in Table 56. Two students added two other options: leading and analyzing data. It is indeed said that leading is not part of research, applied and teaching as it could be part of all. The same holds for analyzing data as it could be either research of applied.

Table 56 Distribution of the type of jobs participants do

Research		10
Applied		10
Teaching		2
Other*	Leading	1
	Analyzing Data	1
Total		24
Missing		9

* Added by the participant him/her/themselves

Start Job

The table below presents the month and year participants started their current job. As shown, most student started their job in 2020.

Table 57 Data when the participants started their current job

	Month	Number of participants	Total per year
2012	June	1	1
2017	September	1	1
2018	August	1	3
	October	1	
	December	1	
2019	February	1	8
	April	1	
	August	1	
	September	2	
	October	2	
	November	1	
2020	January	1	11
	February	1	
	March	3	
	May	2	
	June	1	
	September	2	
	October	1	
Total		24	
Missing		9	

The table presented above shows which of the tasks the participants do the most. The tasks the graduates do the most is: modelling (12) and validating mathematical models (10), both tasks are very mathematical. Seven students added other tasks, which are presented in the table.

Table 58 Type of tasks participants do at their current job and the task they would like to do more in the future

	Which of these tasks are part of your daily job? Multiple answers are possible	Which of the following tasks would you like to do (more) in the future? (Multiple answers are possible)
Teaching	7	13
Communicating mathematics to layman	6	9
Modelling	12	11
Managing	4	7
Testing mathematical models	8	3
Validating mathematical models	10	5
Research in mathematics	8	15
Choice consultancy	8	0
Other	7 (Research in programming, Checking if everything works as it should, Communication and negotiation with clients, Clinical research, Data analysis, Programming)	3 (Communication and negotiation with clients, The models I work with are mainly economic. With this I want to further develop myself)

Most participants would like to do more research in mathematics itself in the future (15) as well as teaching (13) and more modelling (11).

Level of mathematics

When conducting the interviews with alumni, some of them explained that they do not use much mathematics at their internship or at their current job. Some of missed the amount of mathematics during their internship and decided to look for a job position where they could use more of the mathematical knowledge they have. One student also said that she missed being challenged during her internship and master thesis at a company, and is now doing a more research-based job.

Because of this, we would like to know how much mathematics graduates use and apply in their current job. We asked students to rate two statements, both are presented in the table below.

Table 59 The level of mathematics used and applied at participants current job rated by the participants

	I use a lot of mathematics at my job	I apply mathematical knowledge in my job
Strongly disagree	5	1
Somewhat disagree	3	2
Neither agree nor disagree	4	2
Somewhat agree	4	8
Strongly agree	8	10

From this we see that most participants use and apply their mathematics at their job.

Participants who selected strongly/somewhat disagree to the statements in Table 59 were asked if they would have liked to use more of their mathematical knowledge, or if the expectations were also different. The results of this are presented below.

Table 60 Results of the questions 'Would you like to use more of your mathematical knowledge at your current job?' and 'Before you started your job, did you have different expectations of the amount of mathematics you would use in your job?'

Would you like to use more of your mathematical knowledge at your current job?	
Yes, I would like to use more of my knowledge	6
Maybe	2
No	0

Before you started your job, did you have different expectations of the amount of mathematics you would use in your job?	
Yes, I expected to use more of my mathematical knowledge	7
Maybe	0
No, the amount was just as I expected	1

From this we see that most participants who do not use a lot of mathematics at their job, would like to use more of their knowledge. Next to that, most of them also expected to use their mathematical knowledge more.

Current job – Conclusion
This section described the participants work background. As described previously, most students do a research-based job or a job more on the applied side and most participants started their job in 2020.

The most interested finding of this section is that most participants who do not use a lot of mathematics at their job would like to use more of it in the future, and also expected to use more at their job. From this, we could conclude that the students who do not use a lot of mathematics at their job, had different expectations about the job. Could it be that the participants do not have a good view of what the professional career looks like and that if they had more time to gain experience in the work field during the study programme, would they have had better expectations of the job.

G5. Satisfaction Internship & Master Thesis
In this thesis, we would like to narrow the gap between study programme and professional career. For this reason, we would like to see how satisfied the graduates are about the study programme's offered preparation. This section investigates the preparation in form of the internship and doing a master thesis at a company. However, courses offered within the master could prepare students for their professional career and are interesting to be explored. Although, these courses might be worth investigating, the author choose to focus on the internship and the master thesis at a company, because the interviewees mentioned that these are opportunities to explore the professional career.

The participants had to rate the following statements:

1. *The programme prepared me for my professional career*
2. *Thanks to the programme, I have sufficient skills and knowledge to do my job properly*
3. *The programme offered possibilities to gain experience in the labour market.*

As the programme believes that they offer possibilities to gain experience in the labour market, statement three was added, because we would like to know if students agree. However, this statement cannot be used to calculate how satisfied students are with the programme. We decided to omit this statement, and calculate student's satisfaction with only statement 1 and 2. In the table below, MeanPreparation is the mean of all the averages per participants on preparation for professional career by the programme, calculated with only the first two statements.

	N	Minimum	Maximum	Mean	Std
MeanPreparation*	24	2.5	5	4.1250	0.78366

The table above show that even with the third statement omitted, the mean does not change very much. We do see that the standard deviation is larger when only statement 1 and 2 are used, which indicates that the satisfaction is more spread out, instead of close to the mean.

		Statement 1 The programme prepared me for my professional career	Statement 2 Thanks to the programme, I have sufficient skills and knowledge to do my job properly	Statement 3 The programme offered possibilities to gain experience in the labour market*
Valid	Strongly disagree	0	0	1
	Somewhat disagree	1	0	1
	Neither agree nor disagree	7	5	1
	Somewhat agree	6	9	9
	Strongly agree	10	10	12
	Total	24	24	24
Missing	System	9	9	9

* This statement was not used to calculate how satisfied students were with the offered preparation for their professional career.

Table 62 shows that most participants are satisfied with the offered preparation for their professional career.

Participants who scored Strongly Disagree were asked to explain what the reason for this was. However, the survey had a small mistake. All participants were asked to explain why they choose Strongly Disagree also when this was not the case. The participants who choose this, answered the question. The others skipped.

The student who selected Somewhat Disagree for the first statement answered: '*the program prepares mostly scientists'*.

The participant who choose Strongly Disagree for last statement answered: '*The first time I gained experience (in the form of an internship) outside the university was during the second year of my Masters. Too less and too late in my opinion.*' Another students somewhat disagreed with the third statement and mentioned that '*There is a limited amount of time that can be spent in the programme. I don't mind the programme focused on theoretical bases, instead of experience in the labour market*'.

Internship

The master programme obligates students to follow an internship at a company or a government institution. Its goal is to gain experience as a mathematician in a non-mathematic environment. Participants had the possibility to choose between (1) doing an internship at a company as part of the 'Non-Mathematics electives' (18 ECTS) or (2) doing your master's thesis at a company (42 ECTS) or (3) both.

We asked the participants to choose what applied to them, the options are stated in Table 63.

Table 63 Distribution of the participants doing an internship or their master thesis at a company.

I did an internship at a company in my non-mathematics elective part	I followed courses in my non-mathematics elective part	I did my master's thesis at a company	I did my master's thesis at the TU Delft	Not applicable
20	6	19	24	0

When analysing the results, we saw that every participant said that they did their master's thesis at the TU Delft, which is true, because they have to. However, what we intended to obtain was how many students did their master thesis solely at the TU Delft and did not do a project for a company. As we also provided the option if they did their master thesis at a company, we now know how many participants did an external master thesis.

Next to the options about internships and master thesis stated above, it is also possible to do a 12 (ECTS) internship in the non-mathematics elective part, and follow a course to obtain 18 (ECTS) in total. So, students could also do both, or could do all three (internship, courses, and an external master thesis).

As shown in the table above, 20 participants did an internship for the non-mathematics elective part.

| Internship & Master Thesis at company | Internship & Master Thesis at TU Delft | Courses & Master Thesis at company | Courses & Master Thesis at TU Delft | More options | |
				Internship & Courses & Master Thesis TU Delft	Internship
10	6	4	0	2	2

Table 64 presents the possible combinations of doing an internship or master thesis at a company. The table shows that two participants did an internship at a company, followed courses both in their non-mathematics electives part and did their master thesis at the TU Delft.

Another participant choose the options: internship at a company, master thesis at a company and master thesis at the TU Delft. As all the students have to do their master thesis at the TU Delft, we placed this participant at Internship & Master Thesis at a company.

From the table above, we see that most students gained experience in the labour market by doing both an internship at a company and their master thesis at a company. Most student also choose to do an internship instead of doing their master thesis at a company (20 vs 14 respectively). However, these number do not vary much. Next to that, two students also followed courses in their non-mathematics electives part, and two students only mentioned doing an internship at a company.

We asked the people who choose Doing courses and Doing master thesis at the TU Delft, why they did not follow an internship, either as part of your master's thesis, or part of the non-mathematics electives. All students did an internship or did their master thesis at a company (or both), so this question was not applicable. However, the two students who choose courses and master thesis at the TU Delft got this question, but their answers are not used further in this thesis.

Internship – Satisfaction

Studiekeuze123 asked students or graduates how satisfied they are with following an internship and the preparation offered by the programme in the NSE. The section is called *Internship and Programme*: 'Students' average satisfaction rating (scale of 1-5) about the quality of the internship supervision from the programme and the way in which you are prepared for your internship.' The NSE mostly focused on the internship supervision from the programme and the preparation offered by the programme. As told in Chapter 2 the programme does not offer any help during the internship, but only at the start when finding and developing a sufficient internship, or during when something goes wrong. They do not prepare students for their internship by organizing lectures or so, but they explain what the

internship entails in one of the Master Information Meetings[12] (MIM) hosted by the master coordinator.

The average for *Internship and Programme* is non existing on the master Applied Mathematics NSE website in section Satisfaction. When analysing the NSE dashboard, we see that the average is 3.1 (based on 14 respondents). When calculating the average with the number presented per respondent the average is 3 (see Section 2.2). However, it is not exactly clear how they calculate these numbers and which questions are exactly connected to this part. However, Studiekeuze123 placed a document online with the question asked in the NSE 2019 (in Dutch).

In the NSE, participants who did an internship had to rate the 6 statements about the internship on a five-point Likert-scale with option not applicable added (translated from Dutch)

1. The quality of the internship guidance from the study programme
2. The preparation for the internship by the study programme
3. The guidance at your internship by the company or institution where you are doing your internship.
4. What you learned during your internship
5. The connection of the internships with other educational parts

It is expected that statement one and two will be rated low, as the programme does not prepare their students for the internship and does not offer any guidance during. How the third, fourth and fifth statements are rated depends on the student's own experience. One of the staff members asked during the interview if the questions about the internship were stated correctly in the NSE, and what students expect from the programme. As the programme does not offer any guidance, the students could score the first two statements low, or choose not applicable, which could predict the low NSE results (the programme perceived this number as low. (Lopuhaä, 2019, p. 22)

As the programme was interested in how satisfied the students were about the internship, we asked the participants to rate statements about their internship. We did not ask the students to rate the quality of the internship guidance from the study programme nor the preparation for the internship by the programme, as the programme does not offer such help.

Table 65 presents the mean of all the averages of the participants for the internship. The mean is above average (3.4411), and the minimum is a 2.40. In total 20 out of 24 participants did an internship.

Table 65 The mean of all the averages of the participants for the internship

	N	Minimum	Maximum	Mean	Std
MeanInternship	20	2.57	4.75	3.6464	0.67529

[12] Master Information Meetings (MIM) are meetings, in which the master coordinator shares information about the programme and helps student by answering their questions. Information about the internship is also presented there. These meetings are not obligatory.

Table 67 presents the distribution of how the participants rated the statements about the internship.

The statements are developed based on the interviews with the programme and alumni. The programme does not offer any preparation, but offers information about the internship at a MIM. Six statements are about the programme's offered preparation about the internship. An alumnus explained during the internships that it was not entirely clear what was needed to pass the internship and what her/his tasks were at the beginning, so two other statements were added. A list of statements and their mean, min, max and standard deviation later on.

Most statements have an average above three, except for two statements: *It was clear to me what needed to be included in the internship report* (statement five, average of 2.90) and *The programme offered guidelines to pass the internship* (statement six, average of 2.65). Ten students disagreed with statement five, from which six strongly disagreed. Nine students disagreed with statement six, from which 2 strongly disagreed. The standard deviation of statement five is also the highest of all the statements.

Statement five and six were added, because one alumnus said that it was not clear what was needed in the internship report and if the internship itself was valid. As the mean of both statements is below average, the programme could take this into account.

Master Thesis
Every master Applied Mathematics student has to do a master thesis worth of 42 ECTS. The students could choose between doing their master thesis solely at the TU Delft, or together with a company. Student who followed courses as non-mathematics electives, are obliged to do their master thesis with a company.

Of 24 students, 14 students did their master thesis at a company.

Master Thesis - Satisfaction
This section discusses how the participants experienced doing their master thesis at a company. In total seven statements were created for the participants to rate on a 5-point Likert-scale with non-applicable as an extra option (the data was treated as a missing value). The statement are developed based on the interviews with alumni.

Table 66 Mean, min, max and standard deviation of satisfaction Master Thesis at a company

	N	Minimum	Maximum	Mean	Std
MeanMasterThesisCompany*	14	4	5	4.5571	0.33447

* This mean is calculated with only the statement stated in table Table 68 without the last two statements.

The Table 66 shows that the participants are satisfied with their master thesis as the mean is above average.

Conclusion – Internship & Master Thesis

Chapter 2 discussed the preparation offered by the programme. As was discussed, *Internship and Programme* section of the NSE had an average of three. The programme mentioned in the Critical Reflection that students' satisfaction for preparation for the internship is low (Lopuhaä, 2019, p. 22). They do not understand why, but an Industrial Advisory board suggested 'a substantial discrepancy between students' expectations and the support actually offered by the internship coordinator.' (p. 22) The *Internship and Programme* section in the NSE is about the supervision offered by the programme and how students are being prepared for their internship. As the study programme does not offer any supervision, this section in the NSE is not applicable for the master Applied Mathematics. For this reason, we asked the participants of this survey to rate a couple of statements about the preparation of the internship, without asking about how they experienced supervision from the programme.

Overall, the participants were very satisfied with doing an internship and with the programme's offered preparation for it. Students were less satisfied with the information provided about the internship report, and offered guidelines to pass the internship.

As students were also allowed to do their master thesis also at a company, we asked the participants to rate some statements about how they experienced doing their master thesis at a company. Most participants are very satisfied with doing their master thesis at a company.

Overall, the programme offered sufficient information about the internship, as most participants were very satisfied. However, the programme could improve their information about what should be included in the internship report and could offer specific guidelines to pass the internship.

Additional Tables on satisfaction internship

Table 67 Results and Statements to obtain how satisfied students were with their internship

	I enjoyed my internship	I knew what my tasks were before I started my internship	I received sufficient guidance from my company supervisor	I knew what I had to do to pass my internship	It was clear to me what needed to be included in the internship report	The programme offered guidelines to pass the internship	The internship showed me examples of the professional career that lied ahead after completing the programme	The internship prepared me for my professional career	The programme suggested several companies to contact for an internship*	I spoke to other students about their experience, which prepared me for my internship*
Strongly disagree	0	2	0	1	6	2	1	1	4	4
Somewhat disagree	3	4	4	3	4	7	0	3	7	5
Neither agree nor disagree	1	4	2	2	0	3	2	1	3	5
Somewhat agree	2	8	5	8	6	5	5	6	4	6
Strongly agree	14	2	9	6	4	0	11	8	2	0
Total	20	20	20	20	20	17	19	19	20	20
I cannot remember / not applicable						3	1			

* These two statements were added by the author but were removed to calculate how satisfied students were, because these two do not measure satisfaction in the eyes of the author.

Additional Tables on satisfaction master thesis at a company

Table 68 Results and Statements to obtain how satisfied students were with their master thesis at a company

	I enjoyed doing my master's thesis at a company	My university supervisor guided me enough during my master's thesis	My company supervisor guided me enough during my master's thesis	I knew what was needed to pass the master's thesis	Doing my thesis at a company prepared me for my professional career	The study programme offered several companies to contact for a master's thesis*	I found the company by myself*
Strongly disagree	0	0	0	0	0	1	3
Somewhat disagree	0	0	0	1	2	2	2
Neither agree nor disagree	1	0	0	0	0	3	0
Somewhat agree	2	5	5	7	1	3	2
Strongly agree	11	9	9	6	11	4	7
Total	14	14	14	14	14	13	14
I cannot remember / not applicable						1	

* These two statements were added by the author but were removed to calculate how satisfied students were, because these two do not measure satisfaction in the eyes of the author.

H. Literature Review – Adaptability in the workplace

Table 69 Search Term Literature Review on Adaptability in the workplace

	Search Terms	Number of articles
Scopus	(TITLE-ABS-KEY ("Adaptive performance" OR "Adaptive workforce" OR "Adaptive job performance" OR "Adaptability" OR "Adaptivity" OR "Flexibility" OR "Role flexibility" OR "Adaption" OR "Resilience" OR "Career adaptability")) AND (TITLE-ABS-KEY (workplace OR "professional skills" OR "Professional aspects" OR "Employment" OR "Professional practice" OR "Professional development" OR "Professional growth" OR "Professionalization")) AND (TITLE-ABS-KEY ("engineer")) AND (TITLE-ABS-KEY ("individual"))	33
Web of Science	ALL FIELDS: ("Adaptive performance" OR "Adaptive workforce" OR "Adaptive job performance" OR "Adaptability" OR "Adaptivity" OR "Flexibility" OR "Role flexibility" OR "Adaption" OR "Resilience" OR "Career adaptability") AND ALL FIELDS: (workplace OR "professional skills" OR "Professional aspects" OR "Employment" OR "Professional practice" OR "Professional development" OR "Professional growth" OR "Professionalization") AND ALL FIELDS: (engineer) AND ALL FIELDS: (individual)	37

I. Mathematical Data Science

Mathematical Data Science is a course taught at the master programme Applied Mathematics. The course presents 'mathematical aspects of problems related to data science.' (*Mathematical Data Science (WI4231) | Study Guide TU Delft*, n.d.) It consists of two parts: in the first part of the course (Quarter Three of the academic year), students get lectures on mathematical aspects of Data Science, in the second part, students carry out a project for a company. The students work on an existing problem or a question from the industry, and communicate with the project owners. The project owners, or company supervisors, present the case before the start of Q4 (quarter 4). Six and seven weeks later, the students present a solution for the case. Students from all master tracks could do this course as mathematical aspects from all specialisations will be discussed. During the course, the students have to conduct small homework assignments and carry out a project for a company. To complete the course, they have to submit a group report, and have to present their findings and have an oral exam.

The course was founded because of the growing interest in Data Science in society. The programme developed this to tap on the interest of the topic and society's interest. The course is also very popular, because of the subject and the application of theory into practice. Instead of simply implementing mathematical methods, the students actually learn why and how the method works, and have to apply it to an existing case.

Depending on the project and the project description, the students divide the work and work on a part of the project separately, but integrate the results at the end.

The course focuses on sharing information on data science from different angles, finding relevant mathematical knowledge and creating mathematical models. One of the study goals is also to formulate and pose relevant questions together in a group, but the course still focuses on finding a solution for the problem, than on other soft aspects of the project, such as collaboration and communication.

Each course has a couple of study goals which are related to the exit qualification and each qualification is again linked with Meijers' critera (See Chapter 4). One of the criteria is '[a graduate] can work in a team and is able to communicate mathematical knowledge verbally and in writing to specialists and non-specialists.', but none of the study goals says something about working in a team, or about 'good communication with colleagues and non-colleagues' (Meijers et al., 2005, p. 4). The study goal may imply it, but it is thus not a specific study goal for which the students get information about.

I1. Mathematical Data Science & Competencies

Mathematical data science uses a sort of collaborative project-based learning (CBL) approach and/or a problem-based learning approach, which is student-centred, i.e., the students are responsible for their own learning. (Baser et al., 2017; Dillenbourg, 1999; Donnelly & Fitzmaurice, 2005) In collaborative project-based learning, the end product drives the planning, production and evaluation processes. (Donnelly & Fitzmaurice, 2005) In problem-based learning, the project has a clear problem statement or case description and it's up to the students to ask relevant questions, find additional and relevant information and share the information with their teammates. Both learning styles are open-ended, "which

requires that the students make appropriate assumptions related to the product to be designed on their own." (Hadim & Esche, 2002, p. 3) Students are in charge of the project, and the teacher facilitates them to stay on the right track.

Because the problem descriptions presented are either very clear, strict and have a clear goal, or are very broad and open to interpretation, both learning styles apply for this course. The exact end product depends on the company and the problem description.

Baser et al. (2017) investigated how CBL could be added in the curriculum in education. This research showed that the students collaborative skills increased, and that the learning approach increased individual development of IT and collaborative skills, such as shared responsibility for group success, make group decisions, sharing resources and materials, and helping each other. They also found out that teachers should provide feedback and help regularly for successful CBL.

In an interview with a staff member of the programme who taught the course twice and a student who followed the course, the interviewees were asked to describe several uncertain and unpredictable work situations and to describe the type of collaboration they use during the course. The uncertain work situation is listed below:

<div style="border:2px solid orange; padding:1em;">

Not knowing who their project members are

    Not working with friends

Working with students from other faculties or with internationals

Not knowing what kind of mathematics is needed to solve the different projects

Different goals (getting grade nine versus passing the course with a six)

Different level of mathematical knowledge prior to the course

Communication with project owner is difficult

The project itself

    What is possible?

    What kind of data set is delivered?

    What is the project goal?

Some students do not know what to do

Integrating different methods investigated by multiple subgroups into the report

</div>

Textbox 10 Examples of uncertain situations the students encounter during the course Mathematical Data Science

As seen in the list, the students encounter a lot of uncertain work situations and also have to demonstrate interpersonal adaptability because they have to collaborate with others. The teacher said that this course is a way to prepare students for the labour market. So, why not take it to a higher level and also focus on the soft aspects of the course, and dive deeper in how to deal with such situations and how to effectively collaborate with fellow students?

When talking about adding something to the course, the teacher said that the students already have to do so much, and there is also stress in that time. "I would like to say that is

hard enough that nothing needs to be added." (Staff Member 4) So, with this being said, this course does not have a lot of space to add something, which could help narrow the gap.

.J. Additional Tool elements

Situation 1

Internship at an IT company: a graduate had to do a project and use artificial intelligence (A4)

Paulo graduated about a year ago and is currently a PhD student. In 2018, he did an internship at an IT company, where he developed a model predicting specific traffic routes using artificial intelligence. During his internship, he found out that the company did not care about how the method exactly worked. "I had the data, so I just had to clean it up […] and that [method] would just give an answer. At one point I got it right with 70% and they were over the moon." Even though the company was very happy, Paulo was not. He said "I was not very pleased with it. […] I really had no idea why it worked."

During his internship he learned that the industry is result-oriented, i.e., it does not matter how you got the answer, the only thing that matters is getting an answer. In other words, the mathematics used in the industry is less than used at the study programme. Paulo was not happy with this part of the job, and decided to do a PhD after graduation. What would you do in Paulo's case?

> *How would you deal with not using all the mathematics you are used to?*
>
> *What would you do if you were in this situation?*
>
> *How would you feel if you were in this situation?*

Situation 2

Working at a bank: a graduate works on a mathematical method in a bank (A3)

Invanka is a master Applied Mathematics graduate and started working in April 2018. She now works at a large bank, where she works on predictive risk assessment using a mathematical model. At her job, Ivanka collaborates with colleagues to redevelop and improve the model. Her colleagues, however, do not always have the same background as her. She works with people who understand mathematics and kind of know what methods exist, but they do not understand why they use it.

After Ivanka found an improvement, she has to explain the mathematics to managers who do not have the same background, so she simplifies the model until it is explainable and understandable for everyone. She said, 'I can do more, and you run into the fact that a mathematician can build a very difficult model, but then you still have to explain it to managers who have done economics or business.'

Ivanka found out at her current job, that she is not able to use all her mathematical skills and knowledge to improve the model the best she can, because of her colleagues' background. In order words, her colleagues hold her back.

> *What would you do if you were in this situation?*
>
> *How would you feel if you were in this situation?*

Situation 3
Working at a consultancy company: a graduate works on fraud detection

Tim is currently an employee at a consultancy firm, where he works on detecting fraudulence activities. At his job he faces difficult challenges he did not encounter when he studies. Tim says "Money and time are a major component of this, but also legal feasibility (privacy)."

Tim found out that working in company involves more than just mathematics. All this makes the work more difficult than he was used to, but on a different level of difficulty. This has to do with the time pressure, which makes it all much more difficult. The challenge is then to keep the work of high quality.

> *How would you manage this level of difficulty?*
>
> *What do you need to deal with this?*
>
> *What would you do if you were in this situation?*
>
> *How would you feel if you were in this situation?*

Situation 4
PhD: a graduate is now a PhD

Vincent is a PhD-student at a university. During his internship, he found out that he would like to use more of this mathematical skills and knowledge and decided to continue 'studying' by doing a PhD.

During his master programme, he followed a course where the assignment was so big, it looked like something serious. Vincent said "You get those perfect examples, which are actually too well put together, so you do not run into anything. […] No, it's never that beautiful." During his PhD, he works on problems which are not perfect for which a different working method is required.

This working method also requires asking critical questions. By asking these types of questions, he could solve parts of the bigger problem. At the moment, he relies on the questions his supervisors pose.

During his work, he found out that the problems he worked in during his master were too perfect and the type of problems he works on right now requires a different working method.

> *Do you know how to deal with this?*
>
> *How do you deal with this?*
>
> *What would you do if you were in this situation?*
>
> *How would you feel if you were in this situation?*

K. Reflective Learning Log

This Reflective Learning Log is developed by the Career & Counselling Services. (*Reflecting and Recording | Managing Your Career by Career & Counselling Services TU Delft*, n.d.)

Table 70 Reflective Learning Log by Career & Counselling Services

The Event

- What happened?

- When did it happen?

- Who was involved?

- My feelings at the time?

- Significant influences at the time?

- Significant outcomes?

My reflections, highlighting the skills that I was using and developed. What did I do well?

What did I learn?

- About myself?

- About my job/studies?

- Feedback from others involved?

Is there anything I would do differently if this situation occurred again?

Is there anything I would do differently if this situation occurred again?

As a result, I plan to change or improve my:

- Knowledge?

- Skills?

- Attributed?