BACHELOR'S PROGRAMME

DATA SCIENCE AND

KNOWLEDGE ENGINEERING

FACULTY OF SCIENCE AND ENGINEERING

MAASTRICHT UNIVERSITY

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This report was finalized on 21 April 2020.

REPORT ON THE BACHELOR'S PROGRAMME DATA SCIENCE AND KNOWLEDGE ENGINEERING OF MAASTRICHT UNIVERSITY

This report takes the NVAO's Assessment Framework for the Higher Education Accreditation System of the Netherlands for limited programme assessments as a starting point (September 2018).

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

Bachelor's programme Data Science and Knowledge Engineering

Name of the programme:	Data Science and Knowledge Engineering
CROHO number:	50300
Level of the programme:	Bachelor
Orientation of the programme:	Academic
Number of credits:	180 EC
Location(s):	Maastricht
Mode(s) of study:	Full-time
Language of instruction:	English
Submission deadline NVAO:	1 May 2020

The visit of the assessment panel Artificial Intelligence to the Faculty of Science and Engineering of the took place on 28 and 29 October 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Maastricht University
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 16 September 2019. The panel that assessed the bachelor's programme Data Science and Knowledge Engineering consisted of:

- Prof. dr.. A. (Ann) Nowé, professor at the Computer Science Department of the Faculty of Science and the Computer Science group of the Engineering Faculty at the Vrije Universiteit Brussel (Belgium) [chair];
- Prof. dr. W. (Wiebe) van der Hoek, Executive Pro Vice Chancellor and professor at the Department of Computer Science of the University of Liverpool (United Kingdom);
- Dr. ir. J.F.M. (Hans) Tonino, associate professor at the Algorithmics Group of the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS/EWI) and Director of Studies in Embedded Systems at Delft University of Technology;
- Dr. A. (Annerieke) Heuvelink-Marck, senior scientist Software Concepts at Philips Group Innovation & Research in Eindhoven;
- F. (Florence) van der Voort BSc, master's student Artificial Intelligence and Philosophy: Bioethics & Health at the Vrije Universiteit Amsterdam [student member].

The panel was supported by Peter Hildering MSc., who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the bachelor's programme Data Science and Knowledge Engineering at the Faculty of Science and Engineering of Maastricht University was part of the cluster assessment Artificial Intelligence. Between October 2019 and January 2020 the panel assessed 14 programmes at 6 universities. The following universities participated in this cluster assessment: University of Groningen, Maastricht University / Transnational University Limburg, Radboud University, University of Amsterdam, Vrije Universiteit Amsterdam and Utrecht University.

On behalf of the participating universities, quality assurance agency QANU was responsible for logistical support, panel guidance and the production of the reports. Dr Marijn Hollestelle was project coordinator for QANU. Marijn Hollestelle, Barbara van Balen, Peter Hildering and José van Zwieten acted as secretaries in the cluster assessment.

During the site visit at Maastricht University, the panel was supported by Peter Hildering MSc., a certified NVAO secretary.

Panel members
The members of the assessment panel were selected based on their expertise, availability and independence. The panel consisted of the following members:

- Prof. dr. A. (Ann) Nowé, professor at the Computer Science Department of the Faculty of Science and the Computer Science group of the Engineering Faculty at the Vrije Universiteit Brussel (Belgium) [chair];
- Prof. dr. B. (Bart) de Boer, researcher and professor at the Artificial Intelligence lab of the Vrije Universiteit Brussel (Belgium);
- Dr A. (Annerieke) Heuvelink-Marck, senior scientist Software Concepts at Philips Group Innovation & Research in Eindhoven;
- Prof. dr. W. (Wiebe) van der Hoek, Executive Pro Vice Chancellor and professor at the Department of Computer Science of the University of Liverpool (United Kingdom);
- Prof. dr. F. (Frank) Jäkel, principal investigator at the Centre for Cognitive Science of the Technical University Darmstadt (Germany);
- Dr ir E. (Edwin) de Jong, principal Machine Learning scientist at ScreenPoint Medical Nijmegen and mentor/coaching A.I. startups at RockStart;
- Dr. A.P. (André) Meyer-Vitali, senior scientist Data Science group at the IT-department of TNO;
- Dr. C.H.M. (Kees) Nieuwenhuis, Technology Manager and staff member of the CTO Office of Thales Nederland;
- Dr. ir. J. F. M. (Hans) Tonino, associate professor at the Algorithmics Group of the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS/EWI) and Director of Studies in Embedded Systems at Delft University of Technology;
- Prof. dr. C. (Cees) Witteveen, full professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science (EEMCS/EWI), Delft University of Technology;
- M. (Maartje) Stokvis BSc, master's student Data Science for Decision Making at Maastricht University [student member];
- F. (Florence) van der Voort BSc, master's student Artificial Intelligence and Philosophy: Bioethics & Health at the Vrije Universiteit Amsterdam [student member].

Preparation
On 10 May 2019, the panel chair was briefed by QANU on her role, the assessment framework, the working method, and the planning of site visits and reports. A preparatory panel meeting was organised on 28 August 2019. During this meeting, the panel members received instruction on the use of the assessment frameworks. The panel also discussed their working method and the planning of the site visits and reports.

The project coordinator composed a schedule for the site visit in consultation with the Faculty of Science and Engineering. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to Maastricht University, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection existed of 15 theses and their assessment forms for the programmes, based on a provided list of 72 graduates between June 2017 – December 2018. A variety of topics and tracks and a diversity of examiners were included in the selection. The project coordinator and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst all panel members.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation reports and the theses, as well as the division of tasks during the site visit.

Site visit
The site visit to Maastricht University took place on 28 and 29 October 2019. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received.

The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

Report
After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project coordinator for peer assessment. Subsequently, the secretary sent the report to the panel. After processing the panel members' feedback, the project coordinator sent the draft reports to the Faculty in order to have it checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Faculty and University Board.

Definition of judgements standards
In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of the standards:

Generic quality
The quality that, from an international perspective, may reasonably be expected from a higher education Associate Degree, Bachelor's or Master's programme.

Meets the standard
The programme meets the generic quality standard.

Partially meets the standard
The programme meets the generic quality standard to a significant extent, but improvements are required in order to fully meet the standard.

Does not meet the standard
The programme does not meet the generic quality standard.

The panel used the following definitions for the assessment of the programme as a whole:

Positive
The programme meets all the standards.

Conditionally positive
The programme meets standard 1 and partially meets a maximum of two standards, with the imposition of conditions being recommended by the panel.

Negative
In the following situations:
- The programme fails to meet one or more standards;
- The programme partially meets standard 1;
- The programme partially meets one or two standards, without the imposition of conditions being recommended by the panel;
- The programme partially meets three or more standards.

SUMMARY JUDGEMENT

The bachelor's programme Data Science & Knowledge Engineering has a clear, broad profile focusing on the mathematical and technical aspects of AI and data science. It aims for its students to acquire skills through group-based collaboration in an international classroom. Its ILOs are well formulated and reflect the profile, academic orientation and bachelor's level of the programme. They are in accordance with the expectations of the discipline and the professional field through alignment with the full core of the domain-specific KION framework of reference, as well as through input provided by an external advisory board.

The bachelor's programme Data Science and Knowledge Engineering has adequately translated its ILOs into a coherent curriculum. The constructive alignment sessions ensure that the courses remain aligned with the programme's goals, and that all ILOs are sufficiently covered throughout the curriculum. The Project-Centred Learning approach of the programme integrates the various courses and allows the students to apply the knowledge and skills learned in the courses in a practical setting. By offering the programme in English, the programme is able to achieve an international classroom setting that allows for cross-cultural learning and prepares the students for an international professional field. To improve the structure and coherence of the curriculum, the panel recommends preparing a clear overview of the learning lines within the programmes and supports the introduction of portfolios to keep track of the skills training of individual students. It also recommends increasing the role of ethical considerations within the curriculum, to reflect the contemporary debate on this topic within AI and data science.

The programme is feasible, although it needs to pay continuous attention to the level of the students admitted to the programme, specifically with regard to their proficiency in mathematics. The panel supports the measures taken by the programme to improve this. Further, it supports the alignment of deadlines in blocks by block coordinators to facilitate a better spread of the workload over the semester. It is positive about the quality and teaching skills of the teaching staff of the programme, and notes that the students are very positive about the enthusiasm, helpfulness and accessibility of their teachers, as well as the study guidance.

The bachelor's programme Data Science & Knowledge Engineering has a good assessment system. Constructive alignment guarantees that the students are assessed on all ILOs throughout the courses in a coherent and progressive way. This could be improved even further by having the test committee check the exams for their relation to the course learning goals. The programme assesses students on their skills through the projects. The close tutoring during the conduct of projects prevents the possibility of free-riding. The panel supports the planned introduction of student portfolios to provide more insight into which specific projects the students actually achieve the skills-related ILOs in.

The thesis assessment is well-designed, employing two academic supervisors to assess the thesis independently, who seek consensus afterwards. The programme could consider including the two separate prior assessments to the thesis dossier to improve the transparency further. The thesis assessment forms include sufficient qualitative feedback and insightful rubrics. The panel recommends including the relative weight of the subgrades used in the grading on each thesis form with the appropriate motivation in order to make the composition of the final grade more transparent. The Board of Examiners fulfils its role in the quality assurance of assessment very well and has the necessary checks and balances in place to monitor the quality of the exams as well as the theses.

The panel concludes that the theses of the bachelor's programme Data Science & Knowledge Engineering are of a good quality and convincingly show that the programme's ILOs have been achieved by the students. They show that the students have a solid foundation in the technical and mathematical aspects of data science and artificial intelligence, and have acquired good academic skills, even to the point of publishable results for some. This is further demonstrated by the variety in national and international technical master's programmes to which graduates of the programme find their way.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

Bachelor's programme Data Science and Knowledge Engineering

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Student assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

The chair, prof. dr Ann Nowé, and the secretary, Peter Hildering MSc., of the panel hereby declare that all panel members have studied this report and that they agree with the judgements laid down in the report. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 21 April 2020.

DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED FRAMEWORK ASSESSMENTS

Standard 1: Intended learning outcomes
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

Findings

Mission and profile
The bachelor's programme Data Science & Knowledge Engineering is a 180 EC programme organized by the Department of Data Science & Knowledge Engineering (DKE), which is part of the Faculty of Science and Engineering of Maastricht University. It aims to provide students with a solid foundation in data science and knowledge engineering by training them in artificial intelligence (AI), computer science and mathematics. The programme uses Project-Centred Learning (PCL), a variant of Problem-Based Learning (PBL) that emphasises group-wise collaboration to solve problems in various application domains. The objective is that graduates of the programme can pursue a master in Artificial Intelligence, Data Science, Computer Science, Applied Mathematics, Operations Research and related programmes, or a career in the IT industry.

The programme explicitly aims for its students to acquire an international academic orientation. It combines the PCL approach with an international classroom, in which different backgrounds are deliberately mixed in project groups.

Within the Dutch landscape of artificial intelligence bachelor's programmes, the programme has a broad profile with a strong emphasis on the technical and mathematical aspects of the subject. It covers the full core modules of the domain-specific frame of reference of the KION (Kunstmatige Intelligentie Opleidingen Nederland), which was formulated by the Dutch Artificial Intelligence programmes in 2018. The programme adds on to the KION framework by offering courses in mathematical and technical foundations of data science. To keep the programme aligned with the expectations of the academic and professional field, the Department has recently introduced an Advisory Board of stakeholders. The Board includes representatives of companies in data science and AI, other academic programmes in AI and alumni of the programme. It meets twice per year and advises on the content and goals of the programme.

Intended learning outcomes
The goals of the programme have been translated into 29 intended learning outcomes (ILOs) that are listed in Appendix 2. These are structured in line with the five Dublin descriptors for academic bachelor's programmes and are formulated based on the qualifications of the KION framework, extended to include aspects of data science.

The panel studied the profile of the bachelor's programme Data Science & Knowledge Engineering, as well as its ILOs. It concluded that the programme has a solid, mathematically focused profile, geared towards both AI and data science, which is clearly visible in its ILOs. The learning outcomes explicitly include international communication skills and group-wise communication, in line with the didactical concept of the programme. They are well formulated and correspond with the KION Framework for bachelor's programmes in Artificial Intelligence. The connection to the discipline and the professional field is strengthened through the benchmarking with this KION Framework and the input provided by the programme's External Advisory Board. The structuring of the ILOs using the Dublin descriptors for academic bachelor's programmes clearly reflects their academic orientation and bachelor's level.

Considerations

The bachelor's programme Data Science & Knowledge Engineering has a clear, broad profile focusing on the mathematical and technical aspects of AI and data science. It aims for its students to acquire skills through group-based collaboration in an international classroom. Its ILOs are well formulated and reflect the profile, academic orientation and bachelor's level of the programme. They are in accordance with the expectations of the discipline and the professional field through alignment with the full core of the domain-specific KION framework of reference, as well as through input provided by an external advisory board.

Conclusion
Bachelor's programme Data Science and Knowledge Engineering: the panel assesses Standard 1 as 'meets the standard'.

Standard 2: Teaching-learning environment
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

Findings

Curriculum and educational approach
The curriculum of the bachelor's programme Data Science and Knowledge Engineering is structured to accommodate Project-Centred Learning (PCL). PCL is a variant of Problem-Based Learning (PBL), the group-based learning approach used throughout Maastricht University. The students work in small, culturally diverse groups (max. 6 students) to apply the knowledge they gained in the courses in realistic projects. They participate in one project of 6 EC per semester. A semester usually consists of two consecutive 8-week periods, each with three 4 EC courses, followed by a 4-week period in which the students can focus on their project and resit exams. The project runs throughout the entire 20-week semester and typically requires the students to integrate the knowledge and skills provided in the courses of that semester. In order to ensure diversity within the project groups, they are composed by the course coordinator to maximize learning through diversity in an international classroom. Academic and professional skills are offered throughout the courses. Through assignments in the courses and project skills classes, the students practise skills such as presenting, academic writing and interviewing. Specific attention is paid to skills related to group work, such as group project management, dealing with free-riding and conflict, and making full use of group diversity.

The first semester of the third year is dedicated to electives. The students can either follow a selection of electives chosen from 10 courses offered by the department alongside an additional project, follow electives elsewhere at Maastricht University, partake in an exchange semester abroad, or follow an educational minor in cooperation with Fontys Lerarenopleiding in order to obtain an additional degree for teaching qualification in mathematics. They can combine options as long as the total adds up to at least 30 EC. In the second semester of the third year, they follow three additional compulsory courses and spend the remaining 18 EC on their bachelor's project. This is an individual research project carried out under the supervision of a DKE researcher. The full curriculum of the programme is included in Appendix 3.

The programme has its own honours programme for excellent students. Students selected for this honours programme can choose between a business-oriented path (KE@Work) or a research-oriented path (MaRBLE 2.0). In KE@Work, three projects in year 2 and 3 are replaced by an individual project at a selected company. MaRBLE 2.0 replaces two projects in year 2 with a challenging individual research project.

To ensure that all ILOs are covered throughout the courses, the programme applies constructive alignment. In 2018, all course coordinators reformulated their course goals and the associated assessment plan in a joint session with the programme's quality assurance officer. In this session, specific attention was paid to coherence in formulating the course goals and their link to the ILOs of the entire programme. This alignment between the course goals and the programme's ILOs is repeated annually in a session with representatives of the entire programme, including the programme director, Board of Examiners and Programme Committee.

The panel studied the curriculum, as well as the content of a number of courses and projects, and spoke with students and staff about the content of the curriculum. It concluded that the curriculum is well-designed and coherent. The programme's ILOs have been adequately translated into course goals. The regular constructive alignment sessions ensure that the courses remain aligned with the programme's goals, and that all ILOs are sufficiently covered throughout the curriculum. The projects integrate the various courses and ensure a translation of knowledge and skills into practice. According to the panel, the skills learned through the projects are also very valuable for future professions, which often include working in project teams. The panel praises the attention to diversity within the project groups with regard to the international classroom. It thinks that this encourages cross-cultural learning, in line with the educational approach of the programme.

The PCL approach is also highly valued by the students. They indicated that the projects are well implemented and that the group tutors are very approachable and helpful in coaching the project group. They feel that they have ample opportunity to develop their skills. With regard to the ILOs of the programme, they believe that they could use more opportunities to develop their skills concerning the ethical considerations of data science and AI. The AI and Philosophy course is a good basis, but they think that ethics should be a regular topic in all projects. The panel agrees with this and recommends that the programme integrates this more strongly into the programme. It notes that ethics in data science and AI is a major topic on a European level, and suggests to align the programme with this debate.

With regard to the structure of the curriculum, the panel thinks that the programme could benefit from defining specific learning lines. Learning lines on, for instance, mathematics, programming and academic skills will make it transparent to students where the various components of the programme content are being taught within the curriculum. With regard to skills, the learning trajectories should be specified on the level of the individual student due to their integration in group projects. The panel understood that the programme is considering introducing student portfolios, in which students keep track of the various roles they have taken within the project groups and what associated skills they have practised as a result. It fully supports this idea and thinks that this is a good measure to ensure that all students have received sufficient training in all skills and keep challenging themselves to take on new roles within the project groups. This specifically applies to honours students, who practice part of their group work-related skills in a professional context, and as a result might have less freedom to experiment with different roles.

Language and internationalization
In line with the educational approach the faculty, the bachelor's programme Data Science & Knowledge Engineering is taught in English. This facilitates an international classroom in which the students can engage in cross-cultural learning. In addition, English serves as a preparation for the very internationally oriented field of data science and artificial intelligence, as well as the broader field of the ICT sector and the research community. To maintain the quality of English as the language of instruction, all non-native English teaching staff have received training to improve their proficiency in English and are required to reach at least the C1 (near native) level. International students have to pass an English language test to demonstrate their proficiency.

According to the panel, the programme has a well-developed international focus, which is an integral part of its educational concept. It has many cross-border collaborations, such as a standing collaboration with RTWH Aachen University and internship and exchange opportunities in companies

and universities outside the Netherlands. The panel agrees that an English language programme is suitable with regard to the international character of the field. It concludes that sufficient measures are in place to safeguard the English language proficiency of the staff, the quality of which is positively evaluated by the students. The student projects that the panel reviewed show that the students have a good command of English.

The majority of the students (approximately 75%) is non-Dutch. During the site visit, the panel discussed with the programme to what extent this ratio is in line with its vision on internationalization. The programme management explained that due to the location of Maastricht a major part of the regional students is in fact international. As a result, the programme envisions itself as being open to all students who meet the admission requirements, regardless of their nationality. Currently, 25% of the students is regional (Germany and Belgium), and 50% is from other EU and non-EU countries. The programme is satisfied with this balance and is currently not considering an additional selection process. The panel understands this reasoning and thinks that this view on internationalization is adequate given the position of the programme within the region and the field.

Feasibility
The study load of the bachelor's programme is reported by the students to be high, but doable. The block structure with two blocks of three courses per semester and a project running in parallel throughout the entire semester requires the students to stay on track with four subjects at the same time. The students indicated to the panel that the estimate of 40 hours of studying per week is realistic for most of them. To help them get acquainted with this, the programme has a mentor programme for all first-year students, in which the teaching staff helps students with their transition from high school to university, and in many cases also from their home country to the Netherlands. The mentors work closely together with the programme's study advisor, who is also available to provide students with study-related assistance or an individual study plan or redirect them to specialists in case of personal problems in later years. To prevent delays in the thesis process, a strict time schedule applies. Theses can be defended during a conference-like event that is organised twice per year. Through this set-up, the programme aims to give students a clear deadline to work towards.

The programme has a drop-out rate in the first year which fluctuates around 30%, which is comparable with similar programmes. Roughly 60% of the students who continue the programme after the first year, graduate within 4 years. However, the remaining 40% struggles to finish the programme, with some of them (approximately a quarter) dropping out in later years. The programme management attributes this to mismatches of students to the programme, in particular with regard to the mathematics components. The field of AI and data science has become increasingly attractive to students, including ones with a less solid background in mathematics. To remedy this, matching interviews have been introduced for all students to inform them about the content of the programme prior to enrolment. Also, the programme has stepped up its efforts to recognize mathematics deficiencies in the diversity of national and international high school diplomas. Finally, the binding study advice (BSA) threshold has been increased as of 2019/2020 to 45 EC in order to prevent students who fail all four mathematics courses in the first year (16 EC) from continuing.

The students the panel interviewed during the site visit praised their teachers and the guidance they provide. They mentioned the open culture and open door policy, which make them feel welcome to discuss any difficulties they might have with their courses or projects. Due to the diverse inflow of backgrounds and nationalities in the programme, they also feel that they can help each other. They do feel that the workload within the semesters could be better aligned, in particular with regard to deadlines and exams between courses. The programme management has already picked up on these signals and has launched a pilot to introduce block coordinators who are responsible for aligning deadlines of the various courses within a block.

The panel is very positive about the attention paid to the feasibility, success rates and study guidance within the programme, and praises the staff for their dedication to helping and guiding the students.

The fixed timeline for the thesis helps the students with the time management of their research project. The panel values the efforts of the programme to improve the feasibility, including a careful matching of prospective students to the content of the curriculum to prevent mismatches. It encourages the programme to continue with this and to monitor whether the implemented measures indeed increase retention figures. It also thinks that the block coordinators are a good idea and supports the introduction of this measure for all blocks.

Teaching staff
The large majority of teaching staff of the programme is employed by the Department of Data Science & Knowledge Engineering. The staff includes three full professors and 24 associate and assistant professors, who are all involved in research in either AI, data science or applied mathematics. A limited number of staff from other departments are involved in teaching courses on computer science, cognitive science, management and philosophy. Some 89% of the teaching staff holds a PhD, and 80% is in possession of a University Teaching Qualification (BKO). Traditionally, DKE was the only department in the exact sciences within Maastricht University, and it had to organize all of its courses itself, including the programming and mathematics courses. Due to the growth ambitions of the Faculty of Science and Engineering, a staff expansion is planned. The department is currently in the process of hiring new staff, including full professors. This is expected to broaden the range of expertise within the department.

As discussed earlier, the students report very favourably about their teachers. According to them, they are enthusiastic, dedicated to teaching, and very approachable and helpful to their students. The panel praises the programme for this. It is also positive about the attention paid to the professionalization of the teachers, which is reflected in the substantial increase in BKO training within the programme (from 48% to 80% since 2013). The panel expects that the expansion of the Faculty of Science and Engineering will be very beneficial to the programme and will open up opportunities to be embedded in a larger teaching staff in the natural and exact sciences. This will allow for more teaching by experts and a broader range of elective options for students.

Facilities
The bachelor's programme has a number of programme-specific facilities. This includes a computer room with desktops that have the necessary software for students, and the opportunity for students to use a computer cluster at RWTH Aachen University for more advanced computations during their bachelor's research project. The department has its own dedicated robot/swarm lab in which students can work with several robots and the associated hardware. The panel is positive about the programme's facilities. It had the opportunity to visit the robot lab and view a demonstration of student projects. In its opinion, the hands-on experience with machines provides a valuable experience for students to use algorithms and work with data in a real-world setting.

Considerations

The bachelor's programme Data Science and Knowledge Engineering has adequately translated its ILOs into a coherent curriculum. The constructive alignment sessions ensure that the courses remain aligned with the programme's goals, and that all ILOs are sufficiently covered throughout the curriculum. The Project-Centred Learning approach of the programme integrates the various courses and allows the students to apply the knowledge and skills learned in the courses in a practical setting. By offering the programme in English, the programme is able to achieve an international classroom setting that allows for cross-cultural learning and prepares the students for an international professional field. To improve the structure and coherence of the curriculum, the panel recommends preparing a clear overview of the learning lines within the programmes and supports the introduction of portfolios to keep track of the skills training of individual students. It also recommends increasing the role of ethical considerations within the curriculum, to reflect the contemporary debate on this topic within AI and data science.

The programme is feasible, although it needs to pay continuous attention to the level of the students admitted to the programme, specifically with regard to their proficiency in mathematics. The panel supports the measures taken by the programme to improve this. Further, it supports the alignment of deadlines in blocks by block coordinators to facilitate a better spread of the workload over the semester. It is positive about the quality and teaching skills of the teaching staff of the programme, and notes that the students are very positive about the enthusiasm, helpfulness and accessibility of their teachers, as well as the study guidance.

Conclusion
Bachelor's programme Data Science and Knowledge Engineering: the panel assesses Standard 2 as 'meets the standard'.

Standard 3: Student assessment
The programme has an adequate system of student assessment in place.

Findings

Assessment system
The assessment system of the bachelor's programme Data Science & Knowledge Engineering is based on the constructive alignment approach that was discussed under Standard 2. Course coordinators are requested annually to formulate an assessment plan for their course in which they demonstrate alignment between the course learning goals and the assessment within the course. The programme management, Programme Committee and Board of Examiners jointly compose an assessment matrix for the entire programme based on the course assessment plans, and check whether all ILOs are adequately covered in a coherent and progressive way throughout the curriculum.

A written exam with open questions is the main assessment method within the courses, sometimes in combination with assignments. In the case of group assignments, they are not allowed to contribute more than 30% of the total grade in order to prevent free-riding. All exams are checked beforehand for transparency and validity by a test committee mandated by the Board of Examiners. Exams with unexpected results (either too high or too low) and/or low student evaluations are investigated by the Board of Examiners.

The main method of assessment for projects is a written report and a public presentation of the results to the tutor, examiners and fellow project groups. Over the course of a project, the students have formative assessment moments in the form of two intermediate presentations with associated feedback sessions. Grading of projects by two examiners takes place on the basis of the presentations, the written report and an implemented software product (in most cases). A grading form is used which specifies the various subgrades and their weight, as well as written feedback. In principle, the project grade is a group grade applying to all members of the group. The rules and regulations allow for deviation on an individual basis as an exception. This is sometimes used when the tutor notices that the cooperation within groups is far from homogeneous.

The panel studied the assessment system of the programme, the assessment matrix, and some examples of assessment plans, exams and projects. It praises the solid implementation of constructive alignment within the programme, which ensures that all ILOs are assessed within the courses. The check of all exams by the test committee is a good method to increase the validity of the exams. The panel sees room for further improvement of the system by having the test committee check whether all learning goals of the course are adequately assessed in the exam. This would close the loop of constructive alignment and give a full overview on the translation of the programme ILOs to individual exams. The panel thinks that the projects provide a good opportunity to assess skills such as communication, presenting, teamwork and writing. The close tutoring of project groups makes it hard to get away with free-riding behaviour, which was confirmed by both students and staff during the interviews. As discussed under Standard 2, the panel understood that the programme

is considering introducing individual student portfolios to monitor that they fulfil all of the different roles throughout the projects. The panel encourages this, as it would provide more insight into whether students achieve the ILOs associated with the projects.

In the interviews, the students indicated that they would welcome more varied assessment methods in the courses, such as developing software or models. The panel discussed this with the programme. The teaching staff recognized this wish, but thinks that assessment through the development of software and models is too labour-intensive with regard to the limited staff and high student numbers at the moment. The panel acknowledges this and recommends that the programme keep an eye open for future opportunities in this aspect, for instance by decreasing the workload for other forms of assessment through electronic testing.

Thesis assessment
The bachelor's thesis is an individual research project that is conducted under the supervision of a thesis supervisor. This supervisor is usually the first examiner, with another DKE researcher taking the role of second examiner. In the case of a project conducted at an internship organization, the academic supervisor from within the department acts as the first supervisor, with the daily supervisor in the organization as the advisor. Students start their research project by writing a thesis plan using a format provided by the programme, detailing the content of the thesis and the planning. This plan is approved by both examiners and is the formal starting point of the thesis process. When the research is completed, the student writes a bachelor's thesis in the form of a scientific article and gives a public presentation during the bachelor's conference of that semester. Failing to meet this deadline results in a resit; failing the resit means failing the thesis and starting over. The two examiners and, if applicable, the external daily supervisor each formulate their findings independently of each other. After the presentation, the examiners meet, compare their findings and reach consensus on the final grade. They detail this in an assessment form, which includes grades in various subcriteria and a rubric describing which grade is associated with which level.

The panel finds the assessment procedure for the bachelor's thesis to be appropriate. It is positive about the standard inclusion of two academic examiners in the grading, who form their opinion separately from each other before discussing the grade together. The panel studied a number of assessment forms as part of the thesis check conducted prior to the site visit. It concluded that the rubrics and the qualitative feedback provided help to support the grades per category. It did note that there is no fixed weighting attached to the subgrades, which makes it sometimes hard to follow how the final grade was composed from the subgrades. According to the programme, this was done deliberately. Guidelines are provided to the examiners, but within these boundaries the examiners are free to compose the final grade, as not all components are equally applicable to all thesis topics. The panel understands this line of reasoning but thinks that it should at least be made transparent how the subgrades were weighed for a particular thesis. It recommends including the relative weights of each category on the assessment form for each thesis, and providing a written motivation for this choice. Alternatively, the programme could include a fixed weight of subgrades on the assessment form and allow examiners to deviate from this, provided that they motivate their decision on the form. Finally, to improve the transparency of the grading further, the programme could consider including the separate written assessments of the two examiners prior to reaching a consensus in the assessment dossier.

Board of Examiners
The three programmes organized by DKE (the bachelor's programme DSKE and the master's programmes AI and DSDM) share a Board of Examiners. This Board has two members from the programmes, one external member from another faculty, and a secretary. The Board appoints the programme's examiners and monitors the quality of assessment within the programme. It is supported by a test committee consisting of two DKE department members and the faculty's assessment expert. This test committee has a mandate from the Board of Examiners to perform checks on the quality of exams (as discussed above). To check the quality of the theses, the Board

reviews all thesis plans before the start of a bachelor's thesis for their relevance to the programme, as well as cross-checking a selection of graded theses annually.

The panel met the Board of Examiners and studied a number of its annual reports. It judged that the Board fulfils its role in the quality assurance of assessment within the programme very well. It has checks and balances in place to closely monitor the quality of exams as well as theses, and it gave the panel the impression that it is very well aware of its responsibilities within the programme.

Considerations

The bachelor's programme Data Science & Knowledge Engineering has a good assessment system. Constructive alignment guarantees that the students are assessed on all ILOs throughout the courses in a coherent and progressive way. This could be improved even further by having the test committee check the exams for their relation to the course learning goals. The programme assesses students on their skills through the projects. The close tutoring during the conduct of projects prevents the possibility of free-riding. The panel supports the planned introduction of student portfolios to provide more insight into which specific projects the students actually achieve the skills-related ILOs in.

The thesis assessment is well-designed, employing two academic supervisors to assess the thesis independently, who seek consensus afterwards. The programme could consider including the two separate prior assessments to the thesis dossier to improve the transparency further. The thesis assessment forms include sufficient qualitative feedback and insightful rubrics. The panel recommends including the relative weight of the subgrades used in the grading on each thesis form with the appropriate motivation in order to make the composition of the final grade more transparent. The Board of Examiners fulfils its role in the quality assurance of assessment very well and has the necessary checks and balances in place to monitor the quality of the exams as well as the theses.

Conclusion
Bachelor's programme Data Science and Knowledge Engineering: the panel assesses Standard 3 as 'meets the standard'.

Standard 4: Achieved learning outcomes
The programme demonstrates that the intended learning outcomes are achieved.

Findings

Bachelor's theses
Before the site visit, the panel studied 15 bachelor's theses of the programme. It was very positive about their quality. The theses are mathematically sound and demonstrate that the students have obtained a solid foundation in the technical and mathematical aspects of data science and artificial intelligence. The research projects are generally well-designed and show sufficient academic skills and command of the English language. The quality of the theses is further underlined by the fact that 10-15% of the bachelor's theses leads to a scientific publication afterwards, which the panel deems very high.

Performance of alumni
Graduates of the bachelor's programme typically transfer to a master's programme, such as DKE's own master's programmes AI and DSDM or a related programme at another university. The programme does not have exact numbers; due to the international nature of the programme, its graduates end up in many different countries. The programme tries to stay in contact through a LinkedIn group. Data from this group shows that students are admitted to a wide variety of master's programme, such as Computer Science, Information Technology, Operations Research, Logic, Systems Biology and Cognitive Neuroscience. Some are at prestigious research masters, such as at

ETH Zürich, TU Berlin or Charles University. Only a small number of students go directly into industry after completion of their bachelor's programme.

The alumni that the panel interviewed, alumni from both academia and industry, are satisfied with their programme and think that it provided them with the necessary knowledge and skills to be successful, both in academia and in industry. Those about to graduate are confident that they are well-prepared for their master's programme of choice and about their future job perspectives. The panel views this as positive and thinks that the diversity of exit profiles of students towards national and international technical master's programmes as well as the positive attitude of students and alumni are signs that the graduates of the programme successfully achieve the ILOs.

Considerations

The panel concludes that the theses of the bachelor's programme Data Science & Knowledge Engineering are of a good quality and convincingly show that the programme's ILOs have been achieved by the students. They show that the students have a solid foundation in the technical and mathematical aspects of data science and artificial intelligence, and have acquired good academic skills, even to the point of publishable results for some. This is further demonstrated by the variety in national and international technical master's programmes to which graduates of the programme find their way.

Conclusion
Bachelor's programme Data Science and Knowledge Engineering: the panel assesses Standard 4 as 'meets the standard'.

GENERAL CONCLUSION

The panel judged that the bachelor's programme Data Science and Knowledge Engineering offered by Maastricht University meets all the standards of the NVAO assessment framework for limited programme assessment. The panel therefore approves the accreditation of the programme.

Conclusion
The panel assesses the *bachelor's programme Data Science and Knowledge Engineering* as 'positive'.

APPENDICES

APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

Frame of Reference: Bachelor's and Master's Programmes in Artificial Intelligence
The Dutch Perspective
[For author names and article, see:
https://pure.uva.nl/ws/files/29809664/KION_FoR_2018_Final.pdf][1]

October 16th, 2018

This document is an update of the 2013 Frame of Reference as developed by the KION[2] task force on Curricula for
Artificial Intelligence, which was based on:
• Artificial Intelligence Academic Programmes in the Netherlands - A State of the Art report, Quality Assurance Netherlands Universities, 2015[3]
• Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science, The Joint Task Force on Computing Curricula, Association for Computing Machinery (ACM), & IEEE Computer Society, December 20, 2013, p. 221-229[4]
• The Onderwijs- en Examenregelingen (OER) of the bachelor's and master's programmes in Artificial Intelligence administered by the Dutch Universities.
• Tuning Educational Structures in Europe[5], European project, 2000-2004.

1 | INTRODUCTION

This document is an update of the 2013 frame of reference for the Dutch University programmes included in the category Artificial Intelligence of the Dutch register of higher education programmes (CROHO)[6] This frame of reference defines the fields covered by the term Artificial Intelligence as well as the common goals and final qualifications of these programmes.

Artificial Intelligence is a relatively young field. The birth of Artificial Intelligence research is often dated in 1956, when the founding fathers of AI met at the Dartmouth Conference. The history of teaching Artificial Intelligence as a separate discipline is much shorter still, starting in the Netherlands in the early '90's. Consequently, a frame of reference for Artificial Intelligence is still actively developing both in the national and the international context. This document formulates the current Dutch consensus on a national frame of reference for Artificial Intelligence in the Netherlands.

Intelligence is often defined as the ability to reason with knowledge, to plan and to coordinate, to solve problems, to perceive, to learn and to understand language and ideas. Originally these are typical properties and phenomena associated with the human brain, but they can also be investigated without direct reference to the natural system. Both ways of studying intelligence either can or must use computational modelling. The term Artificial Intelligence as used in this document refers to the study of intelligence, whether artificial or natural, by computational means.

1.1 | KION: Artificial Intelligence in the Netherlands

The current Dutch Artificial Intelligence programmes were mostly started in the nineties in an interdisciplinary context. Originally they were known under a variety of names such as Cognitive Science (Cognitiewetenschap), Applied Cognitive Science (Technische Cognitiewetenschap), Knowledge Engineering (Kennistechnologie), Cognitive Artificial Intelligence (Cognitieve Kunstmatige Intelligentie) as well as Artificial Intelligence (Kunstmatige Intelligentie).

[1] The authors like to acknowledge the authors of the 2006 and 2013 Frame of Reference for their work; major parts of this document are still built on their original vision.
[2] Kunstmatige Intelligentie Opleidingen Nederland
[3] www.qanu.nl/en/state-of-the-art-reports (last visited in March 2018)
[4] www.acm.org/education/curricula-recommendations (last visited in March, 2018)
[5] www.unideusto.org/tuning/ (last visited in February 2018)
[6] Centraal Register Opleidingen Hoger Onderwijs

In 1999, the number of recognised labels in the CROHO was reduced, and the aforementioned study programmes were united under the name Artificial Intelligence[7]. Initially, this was an administrative matter that did not influence the content of the curricula. It did mean, however, that from then on cognitive science (as the study of natural intelligence) and artificial intelligence (as a formal approach to intelligence) were shared under the heading of Artificial Intelligence. The above mentioned definition of Artificial Intelligence as the study of natural and/or artificial intelligence by computational means was then agreed upon. The KION (Kunstmatige Intelligentie Opleidingen in Nederland) was formed as a discussion and cooperation platform for the united programmes.

Starting in 2002, all university-level study programmes in the Netherlands were divided into a bachelor's and a master's phase. KION took this as an opportunity to agree upon a common kernel of subjects that would be constituent of every Dutch Artificial Intelligence bachelor's programme, with the aim of advancing an adequate fit of all Dutch bachelor's programmes to all Dutch master's requirements.

Since then, some degree programmes have changed their names for specification and/or marketing purposes. The Human-Machine Communication degree programme in Groningen joined the KION framework soon after the start, in 2004. In 2013, the VU changed the name of its bachelor's in Kunstmatige Intelligentie to Lifestyle Informatics, to better fit their human-oriented approach to AI, which helped to attract a new population of students (including a higher proportion of female students). However, from 2019 on, the bachelor's programme will be taught in English under the name Artificial Intelligence (with a track in Intelligent Systems and a track in Socially Aware Computing). Furthermore, in 2017, Maastricht renamed its bachelor's programme to Data Science & Knowledge Engineering, and changed its master's programme in Operations Research programme to Data Science for Decision Making, to enable more synergy with its master's AI programme. A full list of the degree programmes that are a member of the KION can be found in section 1.2.

During the last decade new developments in Artificial Intelligence (AI) have become increasingly visible to society and the general public. Most appealing successes like IBM's Watson performance and Google's DeepMind victory in AlphaGo, have globally drawn attention. In business, AI's impact on massive data-mining applications in consumer markets may even more revolutionise the use of AI in everyday life.

2 | PROGRAMME CHARACTERISTICS

This section describes definitions regarding the build-up of bachelor's and master's programmes.

2.1 | Areas, Courses, Modules and Topics

A bachelor's programme in Artificial intelligence is organised hierarchically into three levels. The highest level of the hierarchy is the area, which represents a particular disciplinary subfield. The areas are broken down into smaller divisions called modules, which represent individual thematic units within an area. A module may be implemented as a complete course, be covered in part of a course, or contain elements from several courses. Each module is further subdivided into a set of topics, which are the lowest level of the hierarchy. The modules that implement the particular programme (or curriculum) are together referred as the 'body of knowledge'.

2.2 | Core and Elective Courses

By insisting on a broad consensus in the definition of the core, we hope to keep the core as small as possible, giving institutions the freedom to tailor the elective components of the curriculum in ways that meet their individual needs. The core is thus not a complete programme. Because the core is defined as minimal, it does not, by itself, constitute a complete undergraduate curriculum. Every undergraduate programme must include additional elective courses relating to the body of knowledge. This report does not define what those courses should be, but does enumerate options in terms of modules.

[7] In Dutch: Kunstmatige Intelligentie

2.3 | Assessing the Time Required to Cover a Course

To give readers a sense of the time required to cover a particular course, a metric must be defined that establishes a standard of measurement. No standard measure is recognised throughout the world, but within the European Community agreement has been reached upon a uniform European Credit Transfer System[8] (ECTS) in which study load is measured in European Credits (ECs). One EC stands for 28 hours of study time and a full year of study is standardised at 60 EC. In this document, we shall use the EC metric as the standard of measurement for study load.

2.4 | Coping with Change

An essential requirement of any Artificial Intelligence degree is that it should enable graduates to cope with-and even benefit from-the rapid change that is a continuing feature of the field. But how does one achieve this goal in practice? At one level, the pace of change represents a challenge to academic staff who must continually update courses and equipment. At another level, however, it suggests a shift in pedagogy away from the transmission of specific material, which will quickly become dated, toward modes of instruction that encourage students to acquire knowledge and skills on their own.

Fundamentally, teaching students to cope with change requires instilling an attitude that promotes continued study throughout a career in those students. To this end, an Artificial Intelligence curriculum must strive to meet the following challenges:

- Adopt a teaching methodology that emphasises learning as opposed to teaching, with students continually being challenged to think independently.
- Assign challenging and imaginative exercises that encourage student initiative.
- Present a sound framework with appropriate theory that ensures that the education is sustainable.
- Ensure that equipment and teaching materials remain up to date.
- Make students aware of information resources and appropriate strategies for staying current in the field.
- Encourage cooperative learning and the use of communication technologies to promote group interaction.
- Convince students of the need for continuing professional development to promote lifelong learning.
- Provide students with awareness of potential ethical and legal issues the field of Artificial Intelligence.

3 | SHARED IDENTITY

3.1 | Common Role

Apart from the roles academics usually perform in society students of Artificial Intelligence are educated to enrich society with the benefits a formalization of intelligence and intelligent phenomena can provide. In particular this entails that an alumnus of Artificial Intelligence can contribute to the understanding and exploitation of natural and artificial intelligence. This may lead to new technologies but it may also enrich designs, products, and services with intelligence so that they are more effective, more reliable, more efficient, safer, and often require less natural resources. This role, in combination with the interdisciplinary nature of the field, requires the Artificial Intelligence alumnus to be able to contribute to interdisciplinary teams and, in many cases function as an intermediate who facilitates the interaction of (other) domain specialists.

3.2 | Common Requirements

Artificial Intelligence is a broad discipline and many approaches to the study of intelligent phenomena are justified and fruitful. Curricula are therefore often different from their siblings in emphasis, goals, and capabilities of their graduates. Yet they have much in common. Any reputable Artificial Intelligence programme should include each of the following aspects.

[8] https://ec.europa.eu/education/resources/european-credit-transfer-accumulation-system_en (last visited on May 4, 2018)

1. Essential and foundational underpinnings of the core aspects of intelligence. These must be founded on empirical efforts and based on a formal theory, and they may address professional values and principles. Regardless of their form or focus, the underpinnings must highlight those essential aspects of the discipline that remain unaltered in the face of technological change. The discipline's foundation provides a touchstone that transcends time and circumstances, giving a sense of permanence and stability to its educational mission. Students must have a thorough grounding in that foundation.
2. A foundation in the core concepts of modelling and algorithms for implementing intelligence. The construction and use of models (simplified, abstracted and dynamic representations of some phenomenon in reality) is common to many sciences. In Artificial Intelligence, however, model building is central: the field of Artificial Intelligence may actually be defined as trying to model aspects of (formal or natural) intelligence and knowledge. Moreover, models within Artificial Intelligence have specific characteristic: they are computational and therefore necessarily mathematical or formal. Artificial Intelligence-graduates must therefore be able to work with (computational) models at different levels of abstraction and understand the recursive nature of models in Artificial Intelligence. This foundation has a number of layers:
    a. An understanding of, and appreciation for, many of the diverse aspects of intelligence, models of intelligent phenomena, and of algorithms that describe intelligent processes.
    b. Skills to model intelligent phenomena and appreciate the abilities and limitation of these models, if appropriate in comparison with a natural intelligence counterpart.
    c. Skills to model and implement intelligent phenomena on a computer, in particular skills to work with algorithms and data-structures in software.
    d. Skills to design and build systems that are robust, reliable, and appropriate for their intended audience.
3. An understanding of the possibilities and limitations of what intelligent systems can and cannot do. This foundation has a number of levels:
    a. An understanding of what current state-of-the-art can and cannot accomplish, if appropriate in combination with the accomplishment of the natural system that inspired it;
    b. An understanding of the limitations of intelligent systems, including the difference between what they are inherently incapable of doing versus what may be accomplished via future science and technology;
    c. The impact of deploying technological solutions and interventions on individuals, organizations, and society.
4. The identification and acquisition of non-technical skills, including interpersonal communication skills, team skills, and management skills as appropriate to the discipline. To have value, learning experiences must build such skills (not just convey that they are important) and teach skills that are transferable to new situations.
5. Exposure to an appropriate range of applications and case studies that connect theory and skills learned in academia to real-world occurrences to explicate their relevance and utility.
6. Attention to professional, legal and ethical issues such that students acquire, develop and demonstrate attitudes and priorities that honour, protect, and enhance the profession's ethical stature and standing.
7. Demonstration that each student has integrated the various elements of the (under)graduate experience by undertaking, completing, and presenting a capstone project.

3.3 | Shared Background for Bachelor's Programmes

Similar to alumni of programmes such as Physics, Computer Science, and Psychology, all Artificial Intelligence bachelors are expected to share a certain amount of support knowledge, domain specific knowledge, specialised domain knowledge, and a set of skills. The content mentioned below ensures a firm common basis that enables AI bachelors of any Dutch university admission to any Dutch master's programme in AI. At the same time, it allows for a wide range of individual and/or institute specific specialisations. The list is an update (extension) of the shared programme agreed upon by the KION platform in 2013.

3.3.1 | Core Modules (shared between AI Bachelor's Degree Programmes)

The following topics and skills are part of each of the bachelor's programmes, either as a dedicated course or as a substantial topic within one or more courses. The core modules define the 8 key areas of Artificial Intelligence.

3.3.1.1 | Artificial Intelligence (Core) Modules

- Algorithmic Problem Solving (Search, Decision Making, Optimalisation)
- Cognitive Science
- Computational Linguistics
- Context of Artificial Intelligence (History, Philosophy, Ethics)
- Intelligent Autonomous Agents and Multi-Agent Systems
- Interaction (Perception, Human-Computer Interaction, Communication)
- Knowledge Representation and Reasoning
- Machine Learning

3.3.1.2 | Support Module

Computer Science: Algorithms and Data Structures and Programming
Logic: Propositional Logic and Predicate Logic
Mathematics: Calculus, Discrete Mathematics, Linear Algebra, Probability Theory and Statistics

3.3.1.3 | Academic Skills

Apart from curriculum specific skills, the bachelor's programmes support the development of a set of general academic skills. Even though they can be topics in specific modules, they are generally addressed by the appropriate choice of work and assessment methods throughout the curriculum.

- Analytic Skills
- Empirical Methods
- Modelling
- Teamwork
- Written and Oral Communication, Argumentation and Presentation

3.3.2 | Elective Modules (within Artificial Intelligence)

The following list of modules is considered as representative of the AI field at this moment. Given that the different AI programs have different priorities in selecting topics, and assigning topics to either the bachelor's or master's, each bachelor's should offer a substantial subset of the following list as part of their bachelor's programme, either as specific course, or as a substantial part of a broader course (i.e. a module).

- Architectures of Cognition and Cognitive Modelling
- Computational and Cognitive Neuroscience
- Computational Intelligence
- Computer Vision
- Data Mining
- Deep Learning
- ELSA (Ethical, Legal and Social Aspects of AI)
- Evolutionary Algorithms (Genetic Algorithms, Evolutionary Computing)
- Language and Speech Technology
- Neural Networks
- Perception (Computational and Natural)
- Reasoning under Uncertainty
- Reinforcement Learning
- Robotics
- Text Mining and Information Retrieval
- Virtual Reality and Gaming
- Web and Artificial Intelligence

4 | BACHELOR'S PROGRAMME ARTIFICIAL INTELLIGENCE

This section is divided into two parts. Section 4.1 describes the roles that a bachelor ought to be able to perform in society. Section 4.2 describes the final qualifications that bachelors in Artificial Intelligence possess in order to fulfil these roles.

4.1 | Objectives

The objective of the bachelor's programme is to provide students with a suitable basis for a further career, both in education as well as in employment. The bachelor must be prepared for a number of different roles and opportunities.

4.1.1 | Access to Master's Programmes

The bachelor provides the student with the specific knowledge and abilities, exemplified in the form of a bachelor's diploma that allows the bachelor to apply for any master's programme in Artificial Intelligence or other national or international master's programmes, particularly in related disciplines.

4.1.2 | Professional Career

The bachelor prepares for a position in which the student can earn his or her own subsistence. In particular it prepares for:

- Supervised work on a national and international academic level;
- Positions in the modern high-tech society, such as functions in knowledge-intensive companies and knowledge intensive parts of the non-profit sector.

4.1.3 | Academic Skills

The bachelor provides sufficient training in (scientific) reasoning, conduct, and communication to reach internationally accepted standards of academic skills at that level.

4.1.4 | Place in Society

The bachelor's programme provides the bachelor with the knowledge and tools needed to form an informed opinion of the meaning and impact of Artificial Intelligence, and an informed notion of the responsibilities of a specialist in this area.

4.2 | Final Qualifications

The objectives of the bachelor can be specified into final qualifications. To comply with international standards these qualifications are presented below in terms of the Dublin descriptors for the bachelor's profile[9]. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

4.2.1 | Knowledge and Understanding

The bachelor demonstrates knowledge and understanding in a field of study that builds upon and supersedes their general secondary education. Knowledge and understanding is typically at a level at which the bachelor, whilst supported by advanced textbooks, is able to include some aspects at the forefront of their field of study.

We distinguish two levels of qualification: a basic understanding, corresponding to knowledge of the essentials and fundamentals of the field in question, such as knowing what the field is, knowing how to apply knowledge in said field, and knowing how to further develop oneself in the field in question, and an advanced understanding, corresponding to in-depth knowledge about a topic in question.

Qualifications:

1. Basic understanding of the (8) key areas in Artificial Intelligence in accordance with the shared identity.
2. Advanced knowledge of at least one of the key areas in Artificial Intelligence, up to a level that without further requirements grants access to a master programme in this area.

[9] "A Framework for Qualifications of the European Higher Education Area", 2005. (last visited on May 4, 2018)

4.2.2 | Applying Knowledge and Understanding

Bachelors can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems and/or designing systems within their field of study. They are able to analyse and model prototypical Artificial Intelligence problems by using known Artificial Intelligence methods and techniques.

Qualifications:
1. The ability to understand, apply, formulate, and validate models from the domains of Artificial Intelligence.
2. The ability to apply knowledge from the key areas of Artificial Intelligence. (as outlined in 3.3.1.1)
3. The ability to apply knowledge from the support modules of Artificial Intelligence (as outlined in 3.3.1.2)
4. Analytical approach to problem solving and design:
- Ability to comprehend (design) problems and abstract their essentials.
- Ability to construct and develop logical arguments with clear identification of assumptions and conclusions.
5. The ability to submit an argument in the exact sciences (or humanities) to critical appraisal.
6. Analytical and critical way of thought and ability to apply logical reasoning.
7. Openness to interdisciplinary cooperation and ability to effectively participate therein as an academic professional.
8. The ability to create an effective project plan for solving a prototypical Artificial Intelligent problem in a supervised context.
9. Manage one's own learning and development, including time management and organizational skills.
10. The ability to transpose academic knowledge and expertise into (inter)national social, professional and economic contexts.
11. Readiness to address new problems in new areas, emerging from scientific and professional fields.

4.2.3 | Making Judgments

The bachelor has the ability to gather and interpret relevant data (typically within the field of study) and to formulate judgments that include reflection on relevant social, academic or ethical issues.
Qualifications:
1. Ability to critically review results, arguments and problem statements from accepted perspectives in the field of Artificial Intelligence and neighbouring disciplines.
2. Initial competence in search and critical processing of professional literature in Artificial Intelligence.
3. Acquaintance with the standards of academic criticism.
4. Awareness of, and responsible concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from Artificial Intelligence.

4.2.4 | Communication

The bachelor can communicate information, ideas, problems and solutions to audiences of both domain-specialist and a general audience.

Qualifications:
1. Academically appropriate communicative skills; the bachelor can:
- Communicate ideas effectively in written form and through the use of Information and Communication Technology,
- Make effective oral presentations, both formally and informally,
- Understand and offer constructive critiques of the presentations of others.

4.2.5 | Learning Skills

The bachelor has developed those learning skills that are necessary for a successful further study characterised by a high degree of autonomy (typically in the context of a master or a specialist profession).

Qualifications:
1. Reflection on one's own style of thought and working methods and readiness to take the necessary corrective action.
2. Recognise the need for continued learning throughout a professional career

5 |MASTER'S PROGRAMME ARTIFICIAL INTELLIGENCE

This section is divided into two parts. Section 5.1 describes the roles that a master ought to be able to perform in society. Section 5.2 describes the final qualifications that masters in Artificial Intelligence possess in order to fulfil these roles.

5.1 | Objectives

The objective of the master programme is to provide students with a suitable basis for a further career, both in research as well as in the rest of society. The master must be prepared for a number of different roles and careers at key positions in society.

5.1.1 | Access to PhD Programmes

The master programme provides the student with the specific knowledge and abilities, exemplified in the form of a master diploma that allows the master access to a PhD programme in a broad range of disciplines, especially in Artificial Intelligence related disciplines.

5.1.2 | Professional Career

The master programme prepares for a position in which the student can earn his or her own subsistence. In particular, it prepares for:
• Independent work on an academic level, especially at positions where many of the problems have not been
addressed before and where solutions require scientific training
• Key positions in the modern high-tech society, such as higher functions in knowledge-intensive companies and
knowledge-intensive parts of the non-profit sector

5.1.3 | Academic Skills

The master programme provides sufficient training in independent scientific reasoning, conduct, and communication to reach internationally accepted standards of academic skills at that level. Masters can communicate original ideas in their own language and in English to a public of specialists and non-specialists.

5.1.4 | Place in Society

The programme provides the master with the knowledge and tools needed to formulate an informed opinion about the meaning and impact of Artificial Intelligence in society. Masters are able to enrich society with results from contemporary research and oversee the consequences of proposed measures to society and are aware of their responsibility towards society.

5.2 | Final Qualifications

The objectives of the master can be specified into final qualifications. To comply with international standards these qualifications are presented below in terms of the Dublin descriptors for the master's profile[10]. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

[10] Framework_for_Qualifications_of_the_European_Higher_Education_Area (last visited on May 4, 2018)

5.2.1 | Knowledge and Understanding

The master demonstrates knowledge and understanding in a field of study that builds upon and supersedes their bachelor's degree. Knowledge, understanding, and abilities are typically at a level at which the master is able to formulate a feasible research plan in one's own specialisation.

We distinguish three levels of qualification: a basic understanding, corresponding to the minimal level of knowledge that is expected of a Bachelor student, an advanced understanding, meaning students must have in-depth knowledge about a topic that they could easily develop to become a specialist, and specialist knowledge, meaning students are highly skilled (and specialised) in the key area in question.

Qualifications:
1. Basic understanding of all (8) key areas of Artificial Intelligence.
2. An advanced understanding in some of the key areas of Artificial Intelligence.
3. Specialist knowledge of at least one of the key areas in Artificial Intelligence, up to a level that the master can appreciate the forefront of research in that field.

5.2.2 | Applying Knowledge and Understanding

Masters can apply their knowledge and understanding in a manner that indicates a scientific approach to their work or vocation. They are able to handle complex and ill-defined problems for which it is not a priori known if there is an appropriate solution, how to acquire the necessary information to solve the sub-problems involved, and for which there is no standard or reliable route to the solution.

Qualifications:
1. The ability to formulate a project plan for an open problem in a field related to Artificial Intelligence in general and the own specialisation in particular.
2. The ability to determine the feasibility of a proposal to lead to a solution or design as specified.
3. The ability to contribute autonomously and with minimal supervision to an interdisciplinary project team and to profit from the abilities, the knowledge, and the contributions of other team members.
4. The ability to choose, apply, formulate, and validate models, theories, hypotheses, and ideas from the key areas of Artificial Intelligence.
5. The ability to submit an argument in the exact sciences (or humanities) to critical appraisal and to incorporate its essence in the solution of Artificial Intelligence problems.
6. The ability to translate academic knowledge and expertise into social, professional, economic, and ethical contexts.
7. Awareness of, and responsibility concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from original contributions.

5.2.3 | Making Judgments

The master is able to formulate an opinion or course of action on the basis of incomplete, limited and in part unreliable information.

Qualifications:
1. Competence in the search and critical processing of all sources of information that help to solve an open and ill-defined problem.
2. The ability to demonstrate a professional attitude conform the (international) scientific conduct in Artificial Intelligence.
3. The ability to provide and receive academic criticism conform the standards in one specialism of Artificial Intelligence-research.
4. The ability to formulate an opinion and to make judgments that include social and ethical responsibilities related to the application of one's own contributions.
5. The master is able to judge the quality of his or her work or the work of others from scientific literature.

5.2.4 | Communication

The master can communicate information, ideas, problems and solutions to audiences of specialist in (other) research areas and to a general audience.

Qualifications:
1. The master has academically appropriate communicative skills; s/he can:
- Communicate original ideas effectively in written form,
- Make effective oral presentations, both formally and informally, to a wide range of audiences
- Understand and offer constructive critiques of the presentations of others.

5.2.5 | Learning Skills

The master has developed those learning skills that are necessary for a successful further career at the highest professional level. The master is able to detect missing knowledge and abilities and to deal with them appropriately.

Qualifications:
1. Being able to reflect upon one's competences and knowledge and, if necessary, being able to take the appropriate corrective action.
2. The ability to follow current (scientific) developments related to the professional environment.
3. Showing an active attitude towards continued learning throughout a professional career.

6 | INTERNATIONAL PERSPECTIVE

As stated in the introduction, this frame of reference is intended not only for the Dutch national context, but also to put the Dutch Artificial Intelligence programmes into an international perspective, and possibly to serve as a starting point for an internationally agreed frame of reference. The latter possibility is of course dependent upon international debate and agreement, and at this moment it is not clear how to bring this about, or whether it will in fact be possible. What we can and will do in this document is provide a comparison between the frame of reference as developed in the previous sections and a number of known related study programmes in other countries. In doing this, we hope to show that the developed frame of reference is up to par from an international perspective as well as the Dutch national one.

Having said this, we must immediately recognise that the Dutch national context appears to be rather special in that we only know of specialised bachelor-level Artificial Intelligence study programmes at one university outside the Netherlands, namely at Edinburgh (United Kingdom), which have a rather different programme structure than the Dutch (and general European) one. In our discussion of the Dutch frame of reference in international perspective, we will therefore add to our comparison with the Edinburgh study programme by a comparison with bachelor's programmes of study programmes in a related field, notably Cognitive Science. Furthermore, we will compare the Dutch bachelor's qualifications with the requirements for enrolment in Artificial Intelligence master programmes in other countries.

A comparison of master programmes is tricky as well. Although, contrary to bachelor's programmes, there are several well-known specialised Artificial Intelligence master programmes outside the Netherlands, study programmes at the master level are much more divergent than at the bachelor's level. A comparison can therefore only be provided in global, subject-independent, terms.

We have drawn up both the bachelor's and master's degree programme comparisons based on the programme descriptions and course lists received from the involved Universities. However, for the purpose of conciseness, we have left out particular details of the programmes that are largely time-dependent and often change from year to year.

6.1 | Comparison of Bachelor's Programmes

6.1.1 | The Artificial Intelligence Bachelor's Programme in Edinburgh

Edinburgh University (United Kingdom) offers a range of bachelor's degrees related to Artificial Intelligence, one of them in Artificial Intelligence as such, the others in combination with other disciplines (AI & Computer Science, Cognitive Science). An ordinary bachelor's degree consists of 4 years. In order to compare this system with the European standard of a 3-year bachelor's and a 2-year master's programme, we will take the fourth year of the Edinburgh bachelor's programme to be equivalent to the first year of a 2-year master's degree in other European countries, and base our comparison of bachelor's programmes on the first three years.

It should be pointed out that the (first three years of the) AI-related bachelors in Edinburgh show a large variation between them, and an extensive amount of (usually restricted) choices for particular courses within them. In fact, the commonality between the Edinburgh Artificial Intelligence bachelors is smaller than commonality within the Dutch framework. It seems that the wide variation in Edinburgh Artificial Intelligence related bachelor's degrees actually means that the degrees themselves are much more specialised than the Dutch framework proposes, some of them having little or no (cognitive) psychology, others having no mathematics, etcetera.

6.1.2 | The Cognitive Science Bachelor's Programme in Osnabrück

The University of Osnabrück (Germany) offers a three-year (180 EC) bachelor's programme in Cognitive Science. The discipline of Cognitive Science is related to Artificial Intelligence, and may in fact be seen as a flavour of Artificial Intelligence, focused somewhat more towards Cognitive Psychology, and somewhat less towards Engineering. The same key knowledge and skills apply in Artificial Intelligence and in Cognitive Science.

Based on studying both programmes, we conclude that the Dutch frame of reference recognises the same AI-specific areas as both Cognitive Science programmes outside the Netherlands. The Dutch frame of reference devotes as much or more attention to any of these areas as any of those Cognitive Science programmes, with the exception of Cognitive Psychology in Linköping. Moreover, the recognition, in the Dutch frame of reference, that each individual study programme has a specific profile in addition to the communal areas appears to hold for both inspected study programmes outside the Netherlands as well.

6.1.3 | The Symbolic Systems Bachelor's Programme in Stanford

The University of Stanford offers a programme in Symbolic Systems that has a variant in Artificial Intelligence. The list of core requirements of this programme includes, but is not strictly limited to: single and multivariable calculus, probability theory and statistics, discrete fundamentals, programming, philosophy, cognition and neuroscience, natural language and computation and cognition. Students in Artificial Intelligence should also take courses from the topics of knowledge representation and reasoning, natural language processing, learning and robotics and vision. They offer several courses in these topics. They offer a more in-depth application of numerous of these topics as non-core cognate courses, such as machine learning, motion planning, modal logic, automated reasoning, and more advanced levels of philosophy/linguistics (in reality, they offer a wide variety of supplemental courses).

The course units that are denoted are the core of Symbolic Systems and are supplemented by their Artificial Intelligence variant are very similar to the Dutch framework of reference - all of the topics in the core list of Stanford's programme + variant are reflected in our common core to some degree. There seems to be a slightly bigger focus on Philosophy (3/12th of the Symbolic Systems bachelor's core consists of philosophical foundations). The nature of the setup of compulsory core courses in Stanford does allow students to 'somewhat' skip topics that are important in the eyes of the Dutch framework - for example, the framework in Stanford calls for knowledge on 'Computation and Cognition', which ask of the student to take one course from a list ranging from Theoretical

Neuroscience to Neural Networks and Machine Learning. All in all, the frameworks are similar, but the core of Symbolic Systems appears to be a bit less technical than the Dutch framework.

6.1.4 | The Bachelor's Programme Artificial Intelligence at Carnegie Mellon

The Carnegie Mellon University in Pittsburgh has introduced in Fall 2018 the first full Artificial Intelligence bachelor programme of the USA. Their curriculum consists of three cores: a mathematical, computer science and artificial intelligence core. The artificial intelligence core consists of Introductions in AI Representations, Problem Solving, Machine Learning, Natural Language Processing and/or Computer Vision. As electives, one course has to be selected from four clusters: Decision Making & Robotics, Machine Learning, Perception & Language and Human-AI Interaction.

The main difference with the Dutch Framework is the role of Logic; in this framework Propositional Logic and Predicate Logic are explicitly mentioned as support modules, in Pittsburgh logic is part of the Decision Making & Robotics cluster, with courses as Strategic Reasoning for AI and Planning Techniques for Robotics. This is a far more practical approach compared to the theoretical approach of the Dutch Framework.

6.2 | Comparison of Master's Programmes

6.2.1 | The Artificial Intelligence Master's Programme in Edinburgh

The Artificial Intelligence master programme in Edinburgh spans a full 12-month period and consists of two parts: taught and research. During the taught part (8 months), lectures, tutorials and group practicals are followed. The research part (4 months) consists of a major individual research project on which a dissertation is written. There is also the option of completing only the taught part, in which case, a Diploma will be awarded. MSc courses in Artificial Intelligence in Edinburgh are grouped in four major areas of specialisation:

- Intelligent robotics
- Agents, Knowledge and Data
- Machine Learning
- Natural language processing

Comparing the Edinburgh programmes to the Dutch frame of reference, we can draw the following conclusions:

- The main Artificial Intelligence topics that are in the Dutch framework are also represented in the Edinburgh programmes (as shown in the four different identified areas of specialisation).
- The Edinburgh programmes are 1-year, whereas most Dutch Artificial Intelligence master programmes are 2-year programmes. However, the Edinburgh master programme requires a 4-year honours bachelor's degree.
- The Edinburgh programme knows relatively little study load for practical work. Whereas the minimum length of a Dutch master-thesis ('afstudeerproject') is 30 ECs (half a year), the Edinburgh programme has 4 months for doing practical assignments.
- However, the practical work seems to be more research oriented, whereas in the Dutch programme there is also the option to do a final project in industry.
- The Edinburgh program has an entry requirement on mathematics (During the bachelor degree 60 credits have completed of mathematics.)

6.2.2 | The Machine Learning and Machine Intelligence Master's Programme in Cambridge

At the University of Cambridge the master is called Machine Learning and Machine Intelligence. It is a very selective (20 places) two year programme (120 ECTS credits). To apply, the applicants should have a UK First class Honours Degree (equivalent with overall grade of 8/10).

Their programme includes courses such as:

- Deep Learning and Structured Data
- Probabilistic Machine Learning
- Speech Recognition

- Weighted Automata
- Computer Vision

Comparing the Cambridge study programme to the Dutch frame of reference, we can draw the following conclusions:
- the programme has clear programme objectives (9 in total)
- the programme only covers 3 of the 8 core areas (Computational Linguistics, Perception, Machine Learning)
- There is not much choice: the programme consists of eleven core modules
- the programme has only two optional modules: Computer Vision or Natural Language Processing
- As elective the students can pick one elective module from 4th year undergraduate

6.2.3 | The Symbolic Systems and Computing Science Master's Programmes in Stanford

Stanford offers two variants that are similar to Artificial Intelligence in the Netherlands: the Symbolic Systems Master and an Artificial Intelligence variant in the Computer Science degree programme. Symbolic Systems is an interdisciplinary programme that combines Computer Science, Psychology, Philosophy, and Linguistics in order to better understand cognition in both humans and machines. Viewing people and computers as symbol processors, the Symbolic Systems programme explores the ways computers and people reason, perceive, and act. Within the Symbolic Systems major, there is a core set of required classes with respect to the aforementioned fields; beyond this core, students choose an area of concentration in order to gain depth.[11]

The variant that is actually named Artificial Intelligence offers a subset of the disciplines in the Dutch framework, mostly those related to Computer Science. This master´s programme focuses on solving problems using computers, and as such mainly contains course units that address topics in Machine Learning, Computer Vision, Natural Language Processing, Data Mining, Robotics and Bioinformatics. There is a framework of courses students can choose from, but this framework is fairly loosely defined (with only very few guidelines), making it hard to distinguish a core beyond the specific attention for the applied computational side of Artificial Intelligence.

Comparing the Stanford study programme to the Dutch frame of reference can only be done by evaluating both the Symbolic Systems Master and the Computer Variant at the same time:
1. The Dutch framework has more formal subjects (such as a stronger focus explicit focus on logic and computer science related topics) than the Symbolic Systems programme. The Dutch framework has more topics related to Cognitive Science and the context of Artificial Intelligence than the Computer Science AI variant.
2. It has already been mentioned that there is much variety between the master programmes – both in the Netherlands and abroad. This is also the case for the programmes at Stanford.
- The Stanford programmes seem to have a lot of freedom in their choice for electives. In other words, the core of compulsory courses is limited and students have to select many elective courses - thus rejecting the idea behind a broad common core of the programme.

6.2.4 | The Cognitive Science Master's Programme in Osnabrück

The university of Osnabrück offers a two-year (120 ec) master of science programme in Cognitive Science. Apart from a 30 ec individual thesis project and a 22 ec team project, students take predominantly elective courses in Cognitive Psychology, Artificial Intelligence, (Computational) Linguistics, Robotics, Neuroscience, Neuroinformatics and Philosophy of Mind and Cognition. The choice of courses largely follows the research group structure. The programme offers a double degree option together with the Cognitive Science programme in Trento. The Osnabrück programme has a similar focus on cognitive (and neuroscience) aspects of AI as Nijmegen. Nijmegen has a tradition of attracting graduated bachelor students from Osnabrück who are typically directly admitted to the master programme in Nijmegen; in addition, several graduated master students from Osnabrück found a PhD position at the Radboud University. Student mobility thus suggests that the programmes are relatively comparable in content and quality to the Dutch Framework.

[11] http://symsys.stanford.edu/courses (last visited on May 4, 2018)

7 | NATIONAL PERSPECTIVE

At its core, the framework of reference serves as a foundation for every Artificial Intelligence degree programme in the Netherlands. This is also what differentiates the degree programmes that are a member of the KION from similar degree programmes: at its very heart, the KION programmes aim to provide a broad foundation that respects the roots of the field, rather than merely offer a specialistic application of Artificial Intelligence. With the growing popularity and diversity of Artificial Intelligence as a field, the need for programmes to adhere to a framework founded in both history and modern-day application is more important than ever.

We have drawn up an analysis that compares AI-related degree programmes in the Netherlands, to see whether they fit the frame of reference. In this way, we hope to highlight the unique position the KION degree programmes hold in the field of Artificial Intelligence: both with respect to delivering broadly educated Artificial Intelligence students, but also with respect to the consistency of the quality and background future employers can expect.

7.1 | Bachelor's Programmes

Tilburg University and TU Eindhoven offer a joint BSc degree in Data Science. The focus of this bachelor's degree is on mathematical tools for dealing with big data; there is less emphasis on programming and no broad introduction in Artificial Intelligence. Tilburg University also offers a bachelor in Cognitive Science and Artificial Intelligence; this is part of the School for Humanities. Currently, the programme is under development; the relationship with the KION frame of reference is still open at the time of writing. Finally, TU Delft offers a bachelor Computer Science & Engineering (intelligent data analysis variant). This programme does not offer the broad introduction in Artificial Intelligence that the KION degree programmes do.

7.2 | Master's Programmes

Several universities offer a specialisation in Data Science as part of the Computer Science or Information Studies MSc degree. Tilburg University and TU Eindhoven offer a joint MSc degree Data Science and Entrepreneurship. TU Delft offers a MSc degree in Data Science & Technology. These master programmes do not offer the broad overview on AI that the KION degree programmes do, but focus specifically on data science. Tilburg University also offers a one-year MSc degree (in contrast to the two-year KION programmes) in Cognitive Science and Artificial Intelligence.

8 | CONCLUDING REMARKS

Artificial Intelligence is a rapidly developing field. The term Artificial Intelligence does not have the stature of Physics, Psychology, or even Computer Science, due to its relatively recent start as a coherent field of research. Despite this, the recent attention for the successes of the field have ascertained that the field of Artificial Intelligence has made its mark. Internationally, the study of natural and artificial intelligence with computational means is firmly embedded in the fabric of modern Universities.

Modern topics such as gaming, ambient intelligence, ambient awareness, and believable-agent systems are fashionable manifestations of Artificial Intelligence and these and future fashionable spin-offs of Artificial Intelligence will increasingly affect humans. A particularly popular focus of Artificial Intelligence can currently be found in the field of Machine Learning, where possibilities for data analysis provide the world with useful patterns in all sorts of data. These possibilities have helped popularise Artificial Intelligence in the media, but have also raised ethical and legal questions about the field. Future challenges will force products, services, and societies to react faster but remain reliable, to be both flexible and effective, be both efficient and versatile, and to utilise natural resources with maximal benefit. The biggest challenge of all is making the most of this combination of conflicting demands, a challenge that lies very much at the core of in the concept of intelligence.

The Dutch situation is special because of the existence of Artificial Intelligence bachelor's and master's programmes on most of the general universities. This offers the Netherlands a competitive

advantage, consistent with its main economic strategy to remain one of the leading "knowledge intensive" economies. This frame of reference explicates how the bachelor's and master's programmes in Artificial Intelligence of Dutch universities contribute to educate alumni that will take a leading role in meeting these future challenges.

APPENDIX 2: INTENDED LEARNING OUTCOMES

The goals of the programme are as follows:
1. To educate students at an academic level in Data Science and Knowledge Engineering based upon Mathematics, Computer Science, and Artificial Intelligence.
2. To teach students how to analyse and to solve both Data Science and Knowledge Engineering problems in a variety of application domains.
3. To prepare students to work in teams by organizing the education in Data Science and Knowledge Engineering according to the Project-Centred Learning system.
4. To prepare students for further study, in particular the Master programmes in Artificial Intelligence, Data Science for Decision Making and Computer Science offered by the transnational University Limburg (tUL), or for a career in business (IT industry or IT-related application domains).
5. To stimulate students to acquire an international academic orientation.

The 29 qualifications of the programme are as follows:

I. Knowledge and understanding
The recipient of a Bachelor of Science degree in Data Science and Knowledge Engineering should have:
1. Basic understanding of key areas in Data Science;
2. Advanced knowledge of a specific area in Data Science up to a level that without further requirements grants access to a Master programme in this area;
3. Basic understanding of key areas in Artificial Intelligence;
4. Advanced knowledge of a specific area in Artificial Intelligence up to a level that without further requirements grants access to a Master programme in this area;
5. Basic understanding of key areas in Computer Science and in Applied Mathematics;
6. Advanced knowledge of a specific area in Computer Science and in Applied Mathematics up to a level that without further requirements grants access to a Master programme in this area.

II. Applying knowledge and understanding
The recipient of a Bachelor of Science degree in Data Science and Knowledge Engineering should have at least the following thirteen abilities:
7. The ability to understand, apply, formulate, and validate models from the domains of Knowledge Engineering;
8. The ability to extract information from data, to interpret results and to convey them;
9. The ability to apply knowledge from the key areas of Artificial Intelligence;
10. The ability to apply the support modules for Artificial Intelligence;
11. The ability to apply methods and tools from applied mathematics and operations research in particular;
12. The ability for constructing and evaluating mathematical and computational methods for a range of application domains;
13. The ability to submit an argument in the exact sciences to critical appraisal;
14. The ability to think analytically and critically, and to apply logical reasoning;
15. The ability to cooperate in a group and to participate effectively as an academic professional;
16. The ability to create an effective project plan for solving a Data Science and/or Knowledge Engineering problem in a supervised context;
17. The ability to apply Data Science and Knowledge Engineering methods and techniques in a business-related practice;
18. The ability to transpose academic knowledge and expertise in a variety of application domains;
19. Readiness to address new problems in new areas, emerging from scientific and professional fields.

III. Making judgments
The recipient of a Bachelor of Science degree in Data Science and Knowledge Engineering should have:

20. The ability to review critically (a) results, (b) arguments, and (c) problem statements from accepted perspectives in the field of Data Science and Knowledge Engineering;
21. A reasonable level of competence in searching and critically processing the professional literature in Data Science and Knowledge Engineering;
22. A reasonable familiarity with the standards of academic criticism;
23. An awareness of, and responsibility for ethical, normative and social consequences of developments in science and technology, particularly resulting from Data Science and Knowledge Engineering.

IV. Communication
The recipient of a Bachelor of Science degree in Data Science and Knowledge Engineering should have:
24. Academically appropriate communicative skills, i.e., the ability to (a) communicate ideas effectively in written form, (b) give effective presentations, both formally and informally, and (c) understand and offer constructive criticism of the presentations of others;
25. International communication skills;
26. Elementary effectiveness in leading group-wise communication.

V. Learning skills
The recipient of a Bachelor of Science degree in Data Science and Knowledge Engineering should be able to:
27. Reflect on (a) one's own style of thought, (b) one's own working methods, and (c) one's own readiness to take the necessary corrective action;
28. Recognize the need for continued learning throughout a professional career;
29. The ability to manage one's own learning and development.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Year 1

Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Introduction to Computer Science 1; Discrete Mathematics; Introduction to Data Science and Knowledge Engineering	Introduction to Computer Science 2; Linear Algebra; Computational and Cognitive Neuroscience	P R O J E C T	Data Structures and Algorithms; Calculus; ICT and Knowledge Management	Logic; Numerical Mathematics; Software Engineering	P R O J E C T
PROJECT			PROJECT		

Year 2

Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Databases; Probability and Statistics; Philosophy and Artificial Intelligence	Machine Learning; Graph Theory; Reasoning Techniques	P R O J E C T	Theoretical Computer Science; Mathematical Modelling; Human Computer Interaction and Affective Computing	Linear Programming; Mathematical Simulation; *1 out of the electives:* * Natural Language Processing * Introduction to Image and Video Processing	P R O J E C T
PROJECT			PROJECT		

Year 3

Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Semantic Web; Game Theory; Prolog; Computer Security; Robotics and Embedded Systems	Web Applications; Logic for AI; Parallel Programming; Introduction to Bio-Informatics; Software and Systems Verification	P R O J E C T	Data Analysis; Operations Research Case Studies; Intelligent Systems	BACHELOR'S THESIS	
PROJECT			BACHELOR'S THESIS		

* Third year students choose 6 out of 10 optional courses in addition to the semester project in semester 1 of year 3. In case students have passed both electives of period 2.5, either the course Natural Language Processing or Computer Security can replace 1 of the third year electives. Student can also choose (1) elective courses at other UM bachelor programmes of at most 18 ECTS (2) the minor Entrepreneurship or (3) the educational minor.(4) In addition students can study abroad for a semester at one of the exchange partners.

APPENDIX 4: PROGRAMME OF THE SITE VISIT

B Data Science and Knowledge Engineering (MU)
M Data Science for Decision Making (TUL), M Artificial Intelligence (TUL)

Zondag 27 oktober

17.00 – 19.00	Vooroverleg Hotel Beaumont (Lage Barakken 10, Maastricht)
19.00 -	Diner in het hotel

Maandag 28 oktober

08.30 – 09.00	Aankomst visitatielocatie en welkom
09.00 – 10.00	Intern overleg
10.00 – 10.45	**Interview inhoudelijk verantwoordelijken**
10.45 – 11.00	Uitloop / intern overleg
11.00 – 11.45	**Interview studenten bachelor**
11.45 – 12.00	Uitloop/intern overleg
12.00 – 12.45	**Interview docenten bachelor**
12.45 – 13.30	Lunch + inloopspreekuur
13.30 – 14.00	**Rondleiding**
14.00 – 14.45	Uitloop / intern overleg
14.45 – 15.30	**Interview studenten master AI**
15.30 – 15.45	Uitloop / intern overleg
15.45 – 16.30	**Interview studenten master DSDM**
16.30 – 16.45	Uitloop / intern overleg
16.45 – 17.30	**Interview alumni bachelor, master AI & DSDM**
17.30 - 18.00	Intern overleg
19.00 -	Diner Le Courage (Rechtstraat 81, Maastricht)

Dinsdag 29 oktober

08.30 – 09.30	Aankomst visitatielocatie en voorbereiding
09.30 – 10.15	**Docenten Master AI en DSDM**
10.15 – 10.30	Uitloop / intern overleg
10.30 – 11.15	**Interview examencommissie**
11.15 – 11.30	Intern overleg
11.30 – 12.00	**Interview formeel verantwoordelijken**
12.00 – 14.00	Opstellen oordelen (incl. lunch)
14.00 – 14.15	**Mondelinge terugkoppeling**
14.15 – 15.00	Pauze
15.00 – 15.45	**Ontwikkelgesprek**
15.45 – 16.00	Afronding

APPENDIX 5: ADVICE ON PROPOSED NAME CHANGE

Maastricht University
attn. Executive Board

Advice name change bachelor EPA

Dear members of the executive board,

On 28 and 29 November 2019 the assessment panel Artificial Intelligence visited the bachelor's and master's programmes at the Department of Data Science & Knowledge Engineering at Maastricht University, with support provided by evaluation bureau QANU. One of the assessed programmes, the bachelor's programme Data Science & Knowledge Engineering, expressed the wish to change its name to 'Data Science & Artificial Intelligence'. To support the request for name change to the Dutch-Flemish Accreditation Organization (NVAO), the panel was asked for advice on this topic.

During the site visit, the panel discussed the proposed name change with the programme's representatives. The wish for a name change results from the fact that 'Knowledge Engineering' as term has gradually fallen out of use. The programme already had added 'data science' to its name in 2017, but now wants to drop 'knowledge engineering' altogether to be replaced by 'Data Science and Artificial Intelligence', which are currently the most recognized terms to describe this field covered by the bachelor's programme. There is no curriculum change associated with the name change.

The panel agrees with this reasoning. It thinks that 'Knowledge Engineering' is more associated with the past wave of artificial intelligence in the 2000s and is no longer fitting for a modern-day programme. Moreover, 'data science' and 'AI' better reflect the two streams in the programme, and align with the two master's programmes in these fields offered by the department. It therefore concludes that the name 'Data Science & Artificial Intelligence' is fitting with the aims and content of the programme, and judges positively on the proposed name change.

Best regards,

Prof. A. Nowé
Chair assessment panel Artificial Intelligence

APPENDIX 6: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the bachelor's programme Data Science and Knowledge Engineering. Information on the selected theses is available from QANU upon request.

During the site visit, the panel studied, among other things, the following documents (partly as hard copies, partly via the institute's electronic learning environment):

- Overview programme content (study guide, electronic learning environment and a selection of course materials)
- Selection of exam questions and answer models
- Education and Exam Regulation
- Teaching staff overview
- Annual reports Boards of Examiners
- Assessment plans on both programme and course level
- Panel report of the 2013 Programme Assessment