



NVAO • THE NETHERLANDS

PEER REVIEW NEW PROGRAMME

ACADEMIC MASTER

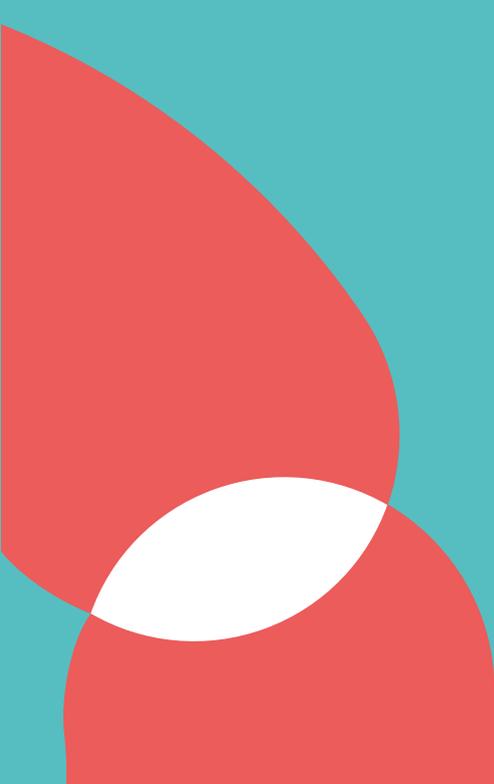
DATA SCIENCE AND ARTIFICIAL

INTELLIGENCE

Eindhoven University of Technology

SUMMARY REPORT

24 November 2020



1 Peer Review

The quality of a new programme is assessed by means of peer review. A panel of independent peers including a student reviews the plans during a site visit to the institution. A discussion amongst peer experts forms the basis for the panel's final judgement and the advisory report. The focus is on the curriculum, the teaching and learning environment, and student assessment.

The Accreditation Organisation of the Netherlands and Flanders (NVAO) takes a formal decision on the quality of the new programme based on the outcome of the peer review. This decision can be positive, conditionally positive or negative. Following a positive NVAO decision with or without conditions the institution can proceed to offer the new programme. Upon completion of the programme graduates are entitled to receive a legally accredited degree.

This summary report contains the main outcomes of the peer review. A full report with more details including the panel's findings and analysis is also available. NVAO bases an accreditation decision on the full report.

Both the full and summary reports of peer reviews are published on NVAO's website www.nvao.net. There you can also find more information on NVAO and peer reviews of new programmes.

Because of COVID-19 temporary measures apply for this peer review.

2 Panel

Peer experts

1. Prof. dr. Ann Nowé (*chair*), Full Professor Computer Sciences and head of the AI Lab, at Vrije Universiteit Brussel, Belgium, *chair*;
2. Prof. dr. Tibor Bosse, Full Professor Artificial Intelligence and Communication Science at Radboud University Nijmegen, President Benelux Association for Artificial Intelligence;
3. Prof. dr. Stan Hoesel, Full Professor at Maastricht University, Member Lectorate Data Analytics at Zuyd University of Applied Sciences;
4. Mr. Menno van Gameren (*student-member*), MSc Business Administration & International Management at University of Amsterdam.

Assisting staff

- Mark Delmartino MA, secretary
- Frank Wamelink, NVAO policy advisor and process coordinator

Site visit (online): 14 October 2020

3 Outcome

The outcome of the initial accreditation of the academic master Data Science & Artificial Intelligence (DS&AI) of the Eindhoven University of Technology is positive. The two-year full-time programme aims to educate engineers who are able to combine advanced data analytics techniques and artificial intelligence methods in order to understand, apply and create systems that behave intelligently and extend human intelligence in a responsible, transparent and explainable way. The Accreditation Organisation of the Netherlands and Flanders (NVAO) organised a peer review and convened a panel of experts. The online visit took place on the 14th of October 2020.

The DS&AI programme results from extensive preparation and is embedded in the vision of the university, the provisions of the Graduate School, and the structure of the Department and its research groups. The intended learning outcomes are formulated adequately in terms of content, level and orientation, reflecting a disciplinary profile that draws from both Data Science and Artificial Intelligence and pays ample attention to ethics and the societal responsibility of engineers. While strongly supporting this profile, the panel does advise the programme to communicate clearly on what the programme offers and what it does not offer in terms of the respective JADS and KION frameworks. Furthermore, in order to monitor the employability of the forthcoming DS&AI graduates, the panel advises the programme to establish a dedicated external Board of Advice.

The teaching and learning environment of the DS&AI programme is strong. The curriculum is well-structured around six specialisation areas and allows students to follow a personalised study programme that fits their individual interests and career ambitions. Student cohorts will consist of Dutch and international bachelor graduates with prior knowledge of DS&AI. The panel welcomes the international classroom setting and advises the programme to make clear admission arrangements with KION universities. The envisaged staff constitutes a mixture of experienced TU/e researchers and newly recruited specialists. They will offer a student-centred learning process featuring knowledgeable mentors, enthusiastic teaching staff who bring their research to the classroom and a master-apprentice approach during the graduation trajectory. Based on the arguments presented by the Department, the panel considers it a logical choice that the new programme is offered in English. Similarly, the panel is convinced that this master programme can only be successfully pursued in a two-year curriculum that consists of 120 EC.

The new DS&AI programme has all components in place for a robust student assessment system. Teaching staff is properly trained for the assessment tasks and the envisaged members of the Examination and Safeguarding Committees have a strong track record in assuring the quality of assessment. All learning outcomes are assessed in an integrated way in the graduation project. The panel appreciates the development work that has gone into the envisaged approach to the final project assessment, yet encourages the programme to safeguard independence of this assessment.

4 Commendations

The programme is commended for the following features of good practice.

1. Development process - the new programme has been prepared extensively in a bottom-up process involving teaching staff, students and company representatives. Teachers and students felt very much involved and found the development process to be enriching and energising.
2. Programme embedding - in setting up the programme, the development team did not have to start from scratch but could rely on policies, regulations and procedures from the University, the Graduate School and the Department.
3. Research-based education - the new programme ties in with the research foci of the Department's research groups; the current research of the envisaged teaching staff is very much in line with the course topics on offer.
4. Ethics - the programme pays attention to ethics, which is explicitly mentioned in the intended learning outcomes and constitutes the subject of a dedicated core course.
5. Staff - the programme does not only rely on a sufficient number of highly qualified staff, but the envisaged teaching staff is also highly enthusiastic about the new programme.

5 Recommendations

For further improvement to the programme, the panel recommends a number of follow-up actions.

1. Board of Advice - the programme's attention to Artificial Intelligence should not jeopardise the technical / engineering competencies for which TU/e graduates are known and appreciated on the labour market. Hence, the panel's advise to establish a dedicated external Board of Advice, including representatives of industry, for the DS&AI programme.
2. DS&AI profile - the new profile draws from both Data Science and Artificial Intelligence yet does not cover either discipline completely. Hence, the panel's advise to communicate clearly what the programme covers and what it does not offer in terms of the respective JADS and KION frameworks.
3. Admission - the programme aims to attract students with some prior knowledge on several domains. The panel suggests to strengthen the programme's admission policy by making good arrangements with KION universities to enable AI bachelor students to prepare for enrolment in this programme.
4. Dual track with EIT Digital Academy - the programme plans to offer DS&AI students the opportunity to enrol on a special track with the EIT Digital Academy. The panel advises the programme to ensure that the high quality of the DS&AI programme is maintained in the arrangements with EIT partner universities. This certainly applies when the final graduation project is performed and assessed abroad, yet becomes part of the requirements for obtaining the master's degree in DS&AI.

6 What comes next?

NVAO grants initial accreditation to a new programme on the basis of a panel's full report. The decision is valid for a maximum of six years. Upon accreditation the new programme will follow the NVAO review procedures for existing programmes. NVAO publishes the accreditation decision together with the full report. A summary report is also available.¹

Each institution has a system of quality assurance in place ensuring continuous follow-up actions and periodic peer-review activities. Peer reviews help the institution to improve the quality of its programmes. The progress made since the last review is therefore taken into consideration when preparing for the next review. The follow-up activities are also part of the following peer-review report. For more information, visit the institution's website.²

7 Summary in Dutch

Het NVAO-panel oordeelt positief over de kwaliteit van de wo-master Data Science & Artificial Intelligence (DS&AI) van de Technische Universiteit Eindhoven. Dit programma beoogt ingenieurs op te leiden met kennis van data-analyse en kunstmatige intelligentie (KI). Het is een academische master van 120 EC en wordt in het Engels aangeboden te Eindhoven.

De master DS&AI werd zeer grondig voorbereid en is ingebed in de universiteit, de *graduate school*, het departement en de onderzoeksgroepen. De beoogde leerresultaten weerspiegelen een disciplinair profiel dat zowel schatplichtig is aan datawetenschap als aan KI. In de opleiding wordt uitgebreid aandacht besteed aan ethiek en aan de maatschappelijke verantwoordelijkheid van ingenieurs. Het panel waardeert die keuzes maar geeft de opleiding wel de raad om duidelijk aan te geven welke componenten uit beide disciplines (datawetenschap en kunstmatige intelligentie) wel en niet aan bod komen in de opleiding en dit in een KION en JADS referentiekader. Om de positionering van toekomstige afgestudeerden op de arbeidsmarkt in kaart te brengen en bijsturing van het programma te ondersteunen, adviseert het panel een externe adviesraad op te richten.

Het curriculum is opgebouwd rond zes specialisatie domeinen en laat studenten toe een gepersonaliseerd programma te volgen dat strookt met hun individuele interesses en ambities. Het panel vindt zowel de opbouw als het maatwerk sterk. De opleiding beoogt een mix van Nederlandse en internationale studenten aan te trekken met een relevant bachelordiploma en enige voorkennis van datawetenschap en KI. De docenten zijn zowel ervaren onderzoekers van de TU Eindhoven als nieuw aangeworven specialisten. Het panel waardeert niet enkel de expertise van de docenten maar ook het enthousiasme waarmee zij en het programmamanagement uitkijken naar de nieuwe opleiding.

De sterke inbedding van de nieuwe opleiding zorgt voor een gedegen en transparant systeem van studentbeoordeling. De docenten hebben de nodige toetsexpertise voor hun beoordelingstaken en de leden van de Examencommissie en de Borgingscommissie hebben ruime ervaring om de kwaliteit van de (eind)toetsen te borgen.

¹ <https://www.nvao.net/nl/besluiten>

² <https://www.tue.nl>

In het afstudeerproject worden alle leerresultaten door drie beoordelaars op een integrale manier getoetst. Het panel waardeert die aanpak en nodigt de opleiding uit om die beoordelaars onafhankelijk van elkaar een eerste appreciatie te laten geven.

De TU Eindhoven stelt voor dat de opleiding een studieduur van twee jaar heeft (120 EC) en in het Engels wordt aangeboden. Het panel heeft kennis genomen van de argumenten van de universiteit en het departement en is van oordeel dat, gezien de breedte en de complexiteit van het curriculum, de opleiding alleen maar succesvol kan worden gevolgd in een tweejarig programma. Ook de Engelse taal is volgens het panel een logische keuze voor dit programma

Meer informatie over de NVAO-werkwijze en de toetsing van nieuwe opleidingen is te vinden op www.nvao.net. Voor informatie over de Technische Universiteit Eindhoven verwijzen we naar de website van de instelling.³

Als gevolg van de beperkende omstandigheden door COVID-19 geldt voor deze kwaliteitstoets een tijdelijke en versnelde procedure.

³ <https://www.tue.nl>



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INITIAL ACCREDITATION

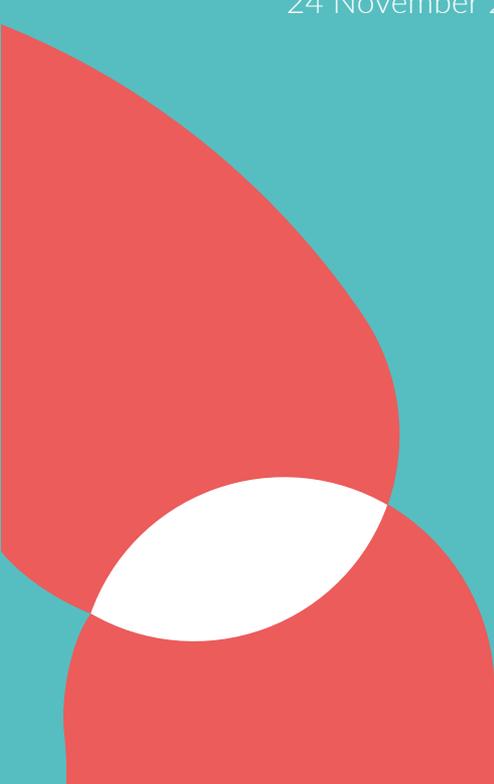
ACADEMIC MASTER

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FULL REPORT

24 November 2020



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1 Peer review

The Accreditation Organisation of the Netherlands and Flanders (NVAO) determines the quality of a new programme on the basis of a peer review. This initial accreditation procedure is required when an institution wishes to award a recognised degree after the successful completion of a study programme.

The procedure for new programmes differs slightly from the approach to existing programmes that have already been accredited. Initial accreditation is in fact an ex ante assessment of a programme. Once accredited the new programme becomes subject to the regular review process.

The quality of a new programme is assessed by means of peer review. A panel of independent peers including a student reviews the plans during a site visit to the institution. A discussion amongst peer experts forms the basis for the panel's final judgement and the advisory report. The agenda for the panel visit and the documents reviewed are available from the NVAO office upon request.

The outcome of this peer review is based on the standards described and published in the limited NVAO Assessment framework for the higher education accreditation system of the Netherlands (Stcrt. 2019, nr. 3198). Each standard is judged on a three-point scale: meets, does not meet or partially meets the standard. The panel will reach a conclusion about the quality of the programme, also on a three-point scale: positive, conditionally positive or negative.

This report contains the findings, analysis and judgements of the panel resulting from the peer review. It also details the commendations as well as recommendations for follow-up actions. A summary report with the main outcomes of the peer review is also available.

NVAO takes an accreditation decision on the basis of the full report. The NVAO decision can be positive, conditionally positive or negative. Following a positive NVAO decision with or without conditions the institution can proceed to offer the new programme.

Both the full and summary reports of each peer review are published on NVAO's website www.nvao.net. There you can also find more information on NVAO and peer reviews of new programmes.

Because of COVID-19 temporary measures apply for this peer review.

2 New programme

2.1 General data

Institution	: Eindhoven University of Technology
Programme	: Data Science and Artificial Intelligence
Mode of study	: full time
Degree	: Master of Science
Tracks	: not applicable
Location	: Eindhoven
Study load	: 120 EC ¹
Field of study	: Technology (confirmed by panel)

2.2 Profile

The department of Mathematics and Computer Science at Eindhoven University of Technology wants to extend its programme portfolio with a MSc in Data Science and Artificial Intelligence. The programme will educate engineers who combine advanced data analytics techniques and artificial intelligence methods in order to understand, apply and create systems that behave intelligently and extend human intelligence in a responsible, transparent and explainable way. The programme plans have been discussed with the external Board of Advice of the department and with a sounding board of current bachelor and master students. A feasibility study indicated that companies recruiting Data Science graduates are looking for specialists in AI, data science and machine learning.

2.3 Panel

Peer experts

1. Prof. dr. Ann Nowé (*chair*), Full Professor Computer Science and head of the AI lab, at Vrije Universiteit Brussel, Belgium, *chair*;
2. Prof. dr. Tibor Bosse, Full Professor Artificial Intelligence and Communication Science at Radboud University Nijmegen, President Benelux Association for Artificial Intelligence;
3. Prof. dr. Stan Hoesel, Full Professor at Maastricht University, Member Lectorate Data Analytics at Zuyd University of Applied Sciences;
4. Mr. Menno van Gameren (*student-member*), student MSc Business Administration & International Management at University of Amsterdam.

Assisting staff

- Mark Delmartino MA, secretary
- Frank Wamelink, NVAO policy advisor and process coordinator

Site visit (online)

14 October 2020

¹ European Credits

3 Outcome

This document reports on the initial accreditation of the academic master Data Science & Artificial Intelligence (DS&AI) of the Eindhoven University of Technology. The two-year full-time programme aims to educate engineers who are able to combine advanced data analytics techniques and artificial intelligence methods in order to understand, apply and create systems that behave intelligently and extend human intelligence in a responsible, transparent and explainable way.

The assessment was carried out by an expert panel convened by the NVAO. The panel reaches a positive conclusion regarding the quality of the new programme. According to the panel, the academic master DS&AI meets each of the three standards of the limited NVAO framework, i.e. intended learning outcomes, teaching-learning environment, and student assessment.

The DS&AI programme results from extensive preparation and is embedded in the vision of the university, the provisions of the Graduate School, and the structure of the Department and its research groups. The intended learning outcomes are formulated adequately in terms of content, level and orientation, reflecting a disciplinary profile that draws from both Data Science and Artificial Intelligence and pays ample attention to ethics and the societal responsibility of engineers. While strongly supporting this profile, the panel does advise the programme to communicate clearly on what the programme offers and what it does not offer in terms of the respective JADS and KION frameworks. Furthermore, in order to monitor the employability of the forthcoming DS&AI graduates, the panel advises the programme to establish a dedicated external Board of Advice.

The teaching and learning environment of the DS&AI programme is strong. The curriculum is well-structured around six specialisation areas and allows students to follow a personalised study programme that fits their individual interests and career ambitions. Student cohorts will consist of Dutch and international bachelor graduates with prior knowledge of DS&AI. The panel welcomes the international classroom setting and advises the programme to make clear admission arrangements with KION universities. The envisaged staff constitutes a mixture of experienced TU/e researchers and newly recruited specialists. They will offer a student-centred learning process featuring knowledgeable mentors, enthusiastic teaching staff who bring their research to the classroom and a master-apprentice approach during the graduation trajectory. Based on the arguments presented by the Department, the panel considers it a logical choice that the new programme is offered in English. Similarly, the panel is convinced that this master programme can only be successfully pursued in a two-year curriculum that consists of 120 EC.

The new DS&AI programme has all components in place for a robust student assessment system. Teaching staff is properly trained for the assessment tasks and the envisaged members of the Examination and Safeguarding Committees have a strong track record in assuring the quality of assessment. All learning outcomes are assessed in an integrated way in the graduation project. The panel appreciates the development work that has gone into the envisaged approach to the final project assessment, yet encourages the programme to safeguard independence of this assessment.

Standard	Judgement
1 Intended learning outcomes	meets the standard
2 Teaching-learning environment	meets the standard
3 Student assessment	meets the standard
Conclusion	positive

4 Commendations

The programme is commended for the following features of good practice.

1. Development process - the new programme has been prepared extensively in a bottom-up process involving teaching staff, students and company representatives. Teachers and students felt very much involved and found the development process to be enriching and energising.
2. Programme embedding - in setting up the programme, the development team did not have to start from scratch but could rely on policies, regulations and procedures from the University, the Graduate School and the Department.
3. Research-based education - the new programme ties in with the research foci of the Department's research groups; the current research of the envisaged teaching staff is very much in line with the course topics on offer.
4. Ethics – the programme pays attention to ethics, which is explicitly mentioned in the intended learning outcomes and constitutes the subject of a dedicated core course.
5. Staff - the programme does not only rely on a sufficient number of highly qualified staff, but the envisaged teaching staff is also highly enthusiastic about the new programme.

5 Recommendations

For further improvement to the programme, the panel recommends a number of follow-up actions.

1. Board of Advice - the programme's attention to Artificial Intelligence should not jeopardise the technical / engineering competencies for which TU/e graduates are known and appreciated on the labour market. Hence, the panel's advise to establish a dedicated external Board of Advice, including representatives of industry ,for the DS&AI programme.
2. DS&AI profile – the new profile draws from both Data Science and Artificial Intelligence yet does not cover either discipline completely. Hence, the panel's advise to communicate clearly what the programme covers and what it does not offer in terms of the respective JADS and KION frameworks.
3. Admission – the programme aims to attract students with some prior knowledge on several domains. The panel suggests to strengthen the programme's admission policy by making good arrangements with KION universities to enable AI bachelor students to prepare for enrolment in this programme.
4. Dual track with EIT Digital Academy – the programme plans to offer DS&AI students the opportunity to enrol on a special track with the EIT Digital Academy. The panel advises the programme to ensure that the high quality of the DS&AI programme is maintained in the arrangements with EIT partner universities. This certainly applies when the final graduation project is performed and assessed abroad, yet becomes part of the requirements for obtaining the master's degree in DS&AI.

6 Assessment

6.1 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.

Judgement

Meets the standard.

Findings, analysis and considerations

The new master programme in Data Science and Artificial Intelligence (DS&AI) has been developed by the Department of Mathematics and Computer Science at Eindhoven University of Technology (TU/e). It intends to educate engineers to master's level who are able to combine advanced data analytics techniques and artificial intelligence methods in order to understand, apply and create systems that behave intelligently and which extend human intelligence in a responsible, transparent and explainable way. This two-year full-time master programme complements the Department's existing programme portfolio of BSc and MSc degrees in mathematics, computer science and data science: whereas data science currently constitutes a track within the master Computer Science and Engineering (CSE), the new MSc DS&AI fills the gap of a dedicated MSc programme in data science. Upon accreditation, it will replace the DS track in the CSE programme. At the same time, the new programme widens the opportunities for students to engage with Artificial Intelligence more prominently than before.

The panel concluded from the information materials and the discussions that the new programme has been prepared extensively in a bottom-up development process involving teaching staff, students and company representatives. The programme plans have been discussed with the research groups that will contribute staff, with the external Board of Advice of the Department and with a sounding board of current bachelor and master students. A labour market feasibility study indicated moreover that companies who have recently been recruiting Data Science graduates are mainly looking for specialists in Artificial Intelligence, Data Science or machine learning. The panel thinks highly of the sheer enthusiasm for the programme that stakeholders – company representatives, students, staff and management – expressed during the interviews. Moreover, the panel was impressed by the envisaged programme leadership and by the co-creative grassroots approach in which ideas from research groups, intended teaching staff and students find their way into the programme.

The programme's core element – and as the panel learned its rather unique selling proposition – is the combination of its two underlying scientific disciplines: data science and artificial intelligence. The programme is organised around six areas: data engineering and management; algorithmic data analysis; explainable data analysis; statistics; data mining and machine learning; and AI and machine learning. Engineers who will graduate from the master DS&AI will be generalists in all fields and specialists in at least two of these key areas. Hence, graduates will be typical TU/e engineers with a distinct π -shaped profile: combining in-depth knowledge in two disciplines with skills to address real-world challenges in science & technology and able to cooperate and communicate with specialists from other domains.

The panel learned that the new programme will be embedded in the Department of Mathematics and Computer Science and comply with the provisions of the TU/e Graduate School. The intended learning outcomes (ILOs) are formulated according to the guidelines of the Graduate School: nine ILOs are common to all master programmes, whereas the formulation of one exit qualification is tailored to the specific domain of DS&AI and further specified in four outcomes. When formulating ILOs, the programme has taken into account the so-called Meijers-criteria, which have been developed by the Dutch universities of technology and cover the Dublin Descriptors in a more detailed way for the domain of Engineering. The panel established that the ILOs are indeed formulated at the adequate level (master) and according to the relevant orientation (academic).

From a disciplinary point of view, the programme has looked into the reference frameworks for data science (JADS) and artificial intelligence (KION). Comparing the six key areas to these frames of reference in the information materials, the panel found that the new programme covers many but not all DS and AI domains. During the interviews, programme representatives provided good arguments for their choices leading to the new, combined DS&AI profile. While strongly supporting the resulting DS&AI profile, the panel does advise the programme to communicate clearly - especially to potentially interested students - what the programme offers and what it does not offer in terms of the respective JADS and KION frameworks.

The panel welcomes the attention to ethics in the programme and applauds the explicit mention of “technical, ethical and social aspects of data collection and of solutions using data science and artificial intelligence techniques” in the ILO. The interviews have furthermore strengthened the panel’s impression that the responsibility of the π -shaped engineer in society is more than a nice buzzword: in fact, teaching staff indicated that they have been reflecting on what a good engineer is and that they address this also in their courses. Students from their side demonstrated convincingly during the interview that they have internalised the π -shaped engineer and are aware of how ethical considerations are shaping their own practice.

The panel gathered from the information materials and the interview with work field representatives that the viewpoint of employers / industry has been taken into account when developing this new master programme. The interview showed that employers are very positive about current TU/e graduates and could not readily indicate how they could be even more positive about the forthcoming DS&AI graduates who will have slightly different competencies. Hence the panel’s advise to establish a dedicated external board of advice for the new master programme that monitors the employability of the new graduates and advises the programme on the competencies DS&AI graduates should acquire during their study in order to enter even more successfully on the labour market.

In line with TU/e policy, students are encouraged to take part in international study programmes. Currently students of the master programme CSE can opt for a special track which is offered by the EIT Digital Academy: the EIT Digital Data Science programme. The Department intends to revise this track, make it data science specific and incorporate this in the new programme DS&AI. When this track is adjusted to fit the new programme, students will be able to follow the programme at two European universities and upon successful completion, obtain a dual degree from the entry point university and the exit point university.

The panel welcomes the attention of the university and the Department for such international partnerships and thinks it will further enlarge the study profile opportunities of individual students. The panel advises the programme to safeguard that the appropriate level is maintained among participating universities. It is important according to the panel that the high quality of the DS&AI programme is safeguarded by proper arrangements with partner universities of the EIT Digital Academy.

In sum, the panel considers that the new master programme DS&AI results from extensive preparation and responds to a need in terms of both education and academic/professional career opportunities. It is embedded in the vision of the university, the provisions of the Graduate School, and the structure of the Department and its research groups. Moreover, the current students look forward to the programme and its additional specialisation opportunities. According to the panel, the intended learning outcomes are formulated adequately in terms of contents, level and orientation, and have been discussed with – and are shared by – the teaching staff. It results in a clear and quite unique disciplinary profile that draws from both DS and AI and pays ample attention to ethics and the societal responsibility of engineers. The panel is convinced that this new engineering programme is well positioned to keep up with forthcoming developments in the professional field and the research environment at the crossroads of DS and AI. Moreover, the resulting π -shaped DS&AI graduates are likely to constitute a value added on the labour market.

6.2 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.

Judgement

Meets the standard.

Findings, analysis and considerations

The new master programme DS&AI is embedded in the university's Graduate School, which ensures the organisational alignment of all master programmes. Hence, the DS&AI curriculum consists of core courses (25 EC), core electives (5 EC), trajectory courses (30 EC), free electives/homologation courses (15 EC), a research seminar (5 EC), a preparation project (10 EC) and a final graduation project (30 EC). The curriculum is structured around the six key areas with their own learning trajectory of three or four courses. The panel has studied the long list of courses in the information materials and was informed that several of these courses are being developed from scratch for the sake of this new master programme. Other courses already exist, yet are currently being adjusted to fit the new learning goals of the course and the intended learning outcomes of the programme. The level of the existing core courses is raised because the new DS&AI students will arrive with more knowledge. Furthermore, each course is described in the programme guide, which also clarifies the contents and learning objectives of the respective trajectories.

The panel learned during the interviews that whatever combination of two areas students decide to choose as specialisation, they will always develop broad knowledge and skills in all areas as well as in the ethical dimension of DS&AI. Moreover, students can fine-tune their own study profile by choosing electives from other disciplines, doing an extra design project, studying abroad or taking an internship. The management and teaching staff confirmed to the

panel during the interviews that such freedom in putting together personalised study programmes is possible because the set of intended learning outcomes is covered through the mandatory courses in combination with the graduation project and the research seminar. Students from their side indicated that they appreciate the variety of specialisation areas and the range of course types, that they grasp the opportunities offered and know that they can get in-house support when fine-tuning their individual study programme. Furthermore, students mentioned that this approach of a broad common basis for all areas and two areas of individual specialism coincides perfectly with the above-mentioned university's vision of a π -shaped engineer. In fact, the interviewed students, who are currently enrolled on other programmes of the Department, found that the extensive preparatory work on this new programme has made the DS&AI curriculum structure and its opportunities even more logical: according to the students, the new programme strikes a good balance between general and specific, without the risk of educating students to become hyper-specialists.

The panel noticed that the DS&AI programme ties in with the research foci of the respective research groups involved in the programme: statistics, visualisation, analytics for information systems, databases, datamining, and artificial intelligence. The teaching staff confirmed during the interview that the learning lines of the DS&AI programme are very much aligned with the research they are currently undertaken. As soon as students are indicating a particular profile preference, teaching staff and envisaged graduate project supervisors can contact their individual international networks and commend / transfer students who wish to study or undertake research abroad to their international colleagues. These arguments have convinced the panel that the education within the new master programme will be research-based and closely aligned with current research of the teaching staff.

The language of instruction for the DS&AI programme will be English. This decision follows from the choice which was made in the Department more than ten years ago to offer all educational programmes in English. The Department wanted – and still wants – to offer bachelor and master programmes in an international environment that students when they graduate are likely to encounter in their future career. Most graduates will work in an organisation in which English is the main language. Computer Science in general, as well as the more specific domains Data Science and Artificial Intelligence are international fields in which English is recognised as the dominant language. English is therefore considered to have substantial value for the students / graduates since it is an elementary requirement on the labour market. The academic staff is also part of this international community: 46% of teaching staff is international, a share that is likely to increase through future recruitment. As of 2020, the international environment will be further strengthened when TU/e switches to English as its lingua franca. In line with the TU/e vision, the new master programme DS&AI aims to attract a heterogenous student influx to offer an international classroom, with about one third international students and two-thirds Dutch students. Based on the arguments that were mentioned in the information materials and have been concretised during the interviews, the panel acknowledges that there is a clear language policy in the Department and at university level that applies to both students and teaching staff. Hence, the panel thinks it is a logical choice to offer the new master programme DS&AI in English.

In line with the university-wide approach on didactics, students are encouraged to be active learners. This requires students to be independent, disciplined and active. There are plenty of opportunities for students to contact teaching staff and researchers during or outside class.

Moreover, students have access to several kinds of advice, support and guidance. Each student will be allocated a mentor, a lecturer whose research is closely related to the specialisation chosen by the student and who assists the student in putting together a coherent study program and development plan. When developing their own study profile, based on their personal interests and possibly career ambitions, students will also get in contact with the most relevant research group and staff members, and build up a master-apprentice relationship with the graduation project supervisor. Furthermore, the panel learned that the programme pays a lot of attention to the hands-on application of theory. Several DS&AI courses include a small group project with common and individual assignments. In the core course Data Intelligence Challenge, students solve a real life problem for which they have to acquire the knowledge themselves within a group setting of students with different specialisations.

Students applying for the new master programme DS&AI will need some knowledge of algorithms, programming and software development, logic and set theory, linear algebra, databases, data structures and visualisation, statistics and data mining/machine learning. According to the information materials, students with a TU/e bachelor degree in Computer Science and Engineering, in Data Science (with a data science major), and in applied mathematics (with the required electives) can enrol directly. Students with a minor deficiency can use the homologation component of the DS&AI programme and take bachelor's level courses up to 15 EC. Students with a larger deficiency, notably students with a bachelor degree of professional orientation, can participate in a pre-master programme of maximum 30 EC. The contents of the homologation / pre-master programme will be discussed with and tailored to the individual needs of the applicant. The panel welcomes the high-level ambitions of the programme with regard to the entry level of DS&AI students and thinks highly of the opportunities offered by the programme to remove minor and larger deficiencies. Nonetheless, the panel invites the programme to contact the KION universities and agree on the admission conditions for their students. Similarly, the programme may want to communicate more explicitly whether bachelor graduates in Computer Science from other Dutch universities can be admitted directly to the DS&AI programme or are expected to follow homologation courses.

The panel gathered from the information materials and the interviews that the programme is borne by a sufficient number of teaching staff with good academic credentials. There are 54 staff (40 FTE) in the participating research groups, while other staff such as lecturers, PhD students and student-assistants are involved in the tutorials. Most faculty have a balanced task load of research and education; younger or newly hired staff can start with a smaller teaching assignment in order to get accustomed to the new environment. The DS&AI programme brings along new courses and new staff in the research groups: the overview in the information materials contains 11 new staff. Interviewees confirmed that the university and the department are actively looking to recruit female staff members. In so far as didactic skills are concerned, more than 80% of the envisaged teaching staff either hold a university teaching qualification or are in the process of obtaining one. In line with TU/e policy, all lecturers teaching in English are expected to have a command of English at C1 level of the Common European Framework of Reference. During the interview, students confirmed the positive results from student surveys: they are satisfied with the expertise and teaching skills of the academic staff, and think their level of English is good. Apart from the above-mentioned finding that the programme can rely on a sufficient number of qualified staff, the

panel thinks highly of the enthusiasm among teaching staff for this new programme. As one interviewee mentioned, the preparation for this programme has a grass roots community feeling because the idea for the programme laid with the department – it was not decided / imposed top down – and the teaching staff was actively involved in moulding the programme into its current shape through a rather enriching and energising process.

In sum, the panel considers that the teaching and learning environment of the new master programme DS&AI is strong, an appreciation that extends to the programme, the staff and the students. The new programme has a clear focus and is strongly embedded in the research groups of the Department. The curriculum is well structured around six specialisation areas and allows students to follow a personalised study programme that befits their individual interests and career ambitions. According to the panel, the envisaged teaching staff constitutes a good mixture of experienced TU/e researchers and newly recruited specialists. The panel welcomes the programme's intention to admit Dutch and international bachelor graduates with prior knowledge of DS&AI. They will be immersed in a student-centred learning process featuring knowledgeable mentors, enthusiastic teaching staff and a master-apprentice approach during the graduation trajectory. Based on the arguments put forward by the department, the panel considers it a logical choice that the new programme is offered in English.

Notwithstanding its positive impression on the curriculum and the six sets of trajectory courses, the panel thinks that the substance of the respective trajectories can be clarified. This also applies to the relevance of the seemingly unlimited trajectory combinations students can choose from. The panel was informed that the Programme Guide provides DS&AI students with clear descriptions on the trajectories and that the team sees it as its explicit task to support students in their choice. Finally, the panel suggests to strengthen the admission policy of the programme by making good arrangements with KION universities and by publicising information on admissions and deficiencies/homologation.

6.3 Standard 3: Student assessment

The programme has an adequate system of student assessment in place.

Judgement

Meets the standard.

Findings, analysis and considerations

The panel gathered from the information materials in the report and its annexes that student assessment in the new master programme DS&AI is well embedded in existing policies and procedures of the TU/e and the Department Mathematics & Computer Science. The programme development team was therefore not obliged to start from scratch, but could use tried-and-tested approaches and materials, which were then adapted where necessary for the sake of the new DS&AI programme. According to the panel, the in-house expertise on which the new programme can rely is extensive, and the work on student assessment that has already been undertaken for the new programme is accurate.

The panel has studied the assessment overview, which describes per course which of the intended learning outcomes at programme level will be assessed, and how. The overview demonstrates that the core and specialisation parts of the programme prepare and

preliminarily assess the learning outcomes of the programmes; the achievement of all ILOs at exit level will be assessed in an integrated way at the research seminar and the final project. Assessment methods differ across courses. The most common assessment methods are written exams and assignments in the form of small projects, usually performed in group and featuring an individual component. In this regard, the panel thinks highly of the Data Intelligence Challenge, a multidisciplinary group project that reflects the university's didactical principle of challenge-based learning and involves several rounds of peer feedback, in addition to group assessment and scores on individual targets and contributions.

Furthermore, the panel learned from the materials and the interviews that examiners have the necessary assessment skills: teaching staff is expected to have or follow UTQ, which includes a separate module dedicated to assessment. As the Examination Committee takes care to appoint only qualified teachers as examiners, it is fair to state that the new DS&AI programme has all prerequisites in place to organise testing in a valid, reliable, transparent and efficient way.

The panel noticed that the graduation project and its assessment have received good attention during the development phase. The final project requires students to individually design and implement a DS and/or AI artefact, to defend their design or theory in a written report, to present it in public and to defend it in a question and answer session following the presentation. Students who wish to do so can perform the final project in a company or do the final project preparation abroad. While the artefact may differ considerably per project and because students can perform their project in any of the Department's research groups, the panel was informed that there are detailed regulations in place to ensure the quality of projects and the standardisation of their assessment: each project/student is assessed by a dedicated assessment committee of at least three members / examiners from different research groups and possibly involves other committee members in an advisory role. Moreover, each committee will judge the quality of the final project using the same set of criteria and will report on its appreciation in a standardised assessment form. The panel found that both criteria and evaluation form are adequate for the assessment of the graduation project as envisaged by the DS&AI programme. The panel did notice, however, that the assessment is negotiated by the examiners at the defence/presentation and does not involve an independent assessment by each of the examiners based on the designed artefact and the report prior to the presentation. In the long-run, the programme may want to consider adding this to strengthen the independence of the assessment of the final graduation project.

The panel spoke to three representatives of current Examination Committees who will each take up a role in the envisaged Examination Committee of the new DS&AI programme. The interviewees have built up extensive expertise over the years and will use this to the benefit of the new programme. To monitor the quality of assessments, the Examination Committee has established a separate Safeguarding Committee (borgingscommissie), which studies samples of examinations and master theses from all programmes in order to check whether assessment and grading are up to standard and comply with the departmental assessment policy. Given that the DS&AI programme will feature several new courses involving some recently hired teaching staff and examiners, the envisaged Examination Committee will ensure that the Safeguarding Committee looks first and foremost at the quality of examinations in these new courses.

Furthermore, the panel was informed that the Safeguarding Committee is currently investigating, on request of the Examination Committee, how to enhance the comparability of grades that have been awarded at partner universities in international tracks. The Examination Committee emphasised that the concern is not the DS&AI courses taken abroad as part of an Erasmus exchange. However, the findings of the Safeguarding Committee are relevant for those DS&AI students who enrol for the dual degree EIT Digital Master School in Data Science and do their exit year at an accredited partner university. In principle, such students follow the set-up and regulations of the partner university. However, if the students' final graduation project is performed and assessed abroad yet becomes part of the requirements for obtaining the master's degree in DS&AI, then the programme may want to double-check the quality and the grade obtained by the students. Moreover, the Examination Committee will have to safeguard that the student has indeed achieved all learning outcomes. The panel welcomes this investigation and advises the programme management and the Examination Committee to take appropriate action following the report from the Safeguarding Committee.

In sum, the panel considers that the new DS&AI programme has all components in place for a robust student assessment system. According to the panel there is a clear link between the intended learning outcomes, the respective courses on offer and their assessment methods, which in turn are relevant for establishing whether students indeed achieve the intended learning outcomes. However, given that students choose not only two out of six specialisation trajectories but have ample freedom to compose their individual programme with other electives at TU/e or abroad, there may be room for a more systematic check whether each combination of trajectories is likely to contribute more or less equally to reaching the intended learning outcomes. Teaching staff is (being) properly trained for the assessment tasks and the envisaged members of the Examination Committee and Safeguarding Committee have a strong track record in assuring the quality of assessment. All learning outcomes are assessed in an integrated way in the graduation project. The panel appreciates the development work that has gone into the envisaged approach to the final project assessment yet invites the programme to consider adding a truly independent component to this assessment.

6.4 Degree and field of study

The panel advises awarding the following degree to the new programme: Master of Science. The panel supports the programme's preference for the following field of study: Technology.

6.5 Programme extension

The Eindhoven University of Technology proposes that the master programme DS&AI has a duration of two years (120 EC). The Department's arguments concern the international requirements towards an academic degree in engineering, the demands of the professional field, and the breadth and complexity of the multidisciplinary programme. The panel has assessed the arguments, using the criteria put forward in the Protocol for programme extension of NVAO, published on 8 October 2003.

Findings, analysis and considerations

The panel is convinced that for DS&AI students to be truly competitive on an international market, they master the knowledge in both data science and artificial intelligence. The professional field demands a combination of strong data science education with knowledge of artificial intelligence. The panel is of the opinion that the range of disciplines, state-of-the-art technical knowledge, and transferrable skills to work effectively in multidisciplinary environments, are essential to the programme. The panel strongly feels that the qualifications graduates should have to be competitive in the international academic job market cannot be achieved in a programme of less than two years.

Furthermore, the panel notes that master programmes in engineering generally have a duration of two years since the introduction of the bachelor and master programmes in the Netherlands. Academic engineering programmes in the Netherlands were set to a duration of five years (300 EC: three years bachelor, two years master studies) in order for students to attain an internationally comparable level. In the case of this new master programme DS&AI, the panel finds the benchmark study conducted by the programme management relevant and thorough, and concludes that nearly all similar master programmes abroad take two years (120 EC). According to the panel, graduates of the DS&AI programme need a two-year master programme in order to achieve the intended learning outcomes.

Conclusion

Given the strong arguments in favour of a two-year curriculum, the panel advises to grant the Eindhoven University of Technology the right to offer the new DS&AI programme as a two-year master programme (120 EC).

Abbreviations

AI	Artificial Intelligence
BSc	Bachelor of Science
CSE	Computer Science and Engineering
DS	Data Science
DSiE	Data Science in Engineering
EC	European Credits
ILO	Intended learning outcomes
JADS	Jheronimus Academy of Data Science
KION	Kunstmatige Intelligentie Opleidingen in Nederland
MSc	Master of Science
NVAO	Accreditation Organisation of the Netherlands and Flanders
TU/e	Eindhoven University of Technology

