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Artificial Intelligence & Engineering Systems
Eindhoven University of Technology

Assessment of conditions

Contents

Summary

The panel concludes that the MSc AI&ES has convincingly strengthened the alignment between the programme aims and the curriculum, and thus fulfilled the conditions set for accreditation.

The programme's vision and aims have been further developed and strengthened, and translated into a coherent curriculum in which the tracks all contribute to the realization of the programme's ILOs in a comparable way. The introduction of four themes in the core elements of the curriculum safeguards that students encounter relevant knowledge and skills in AI and engineering systems in a comparable way. The design of the tracks has been adjusted in such a way that they are much more coherent in terms of content, organization and procedures. Their set-up now follows naturally from the programme's vision to offer specialization within a specific application domain. The AI Foundation and Science track has been renamed and redesigned into a Science and Discovery track, making it comparable in set-up with the other tracks. The new curriculum structure and the alignment of the tracks also allow postponing the choice of a track until later in the first year. Multidisciplinarity has been strengthened in an impressive way in the entire curriculum in a thorough process that includes many internal and external stakeholders, turning it from a concern into a strength of the programme.

Overall, the panel is convinced that the programme has taken the advice and suggestions from the initial accreditation to heart. It has responded constructively, using input from relevant stakeholders resulting in solid educational practices. The condition and its actions as well as additional recommendations on for instance the feedback cycle and examination were extensively addressed, leading to the necessary changes to the teaching-learning environment.

Score table

The panel assesses the programme as follows:

M Artificial Intelligence & Engineering Systems

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**

Prof. dr. ir. Inald Lagendijk (chair)   Peter Hildering MSc (secretary)
Date: 2 October 2023

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Introduction

Procedure

Context

The initial assessment of the master Artificial Intelligence & Engineering Systems (AI&ES) of Eindhoven University of Technology (TU/e) took place on 22 October 2021. The assessment followed the procedure and standards of the NVAO Assessment Framework for the Higher Education Accreditation System of the Netherlands (September 2018).

An external panel reached a conditionally positive conclusion, and advised the NVAO to accredit the programme conditionally due to an issue it encountered in the alignment of ILOs and courses concerning standard 2 (Teaching-Learning Environment). Based on the panel report, the NVAO conceded the programme conditional accreditation, requiring the programme to provide the NVAO with an additional panel report demonstrating that the conditions were met by 20 December 2023.

Preparation

The TU/e requested quality assurance agency Academion to coordinate the assessment of conditions. Peter Hildering MSc of Academion acted as coordinator and secretary of the assessment. He has been certified and registered by the NVAO.

In communication with the TU/e and the M AI&ES, Academion approached the panel members who made up the initial accreditation panel in 2021:

- Prof. dr. ir. Inald Lagendijk (chair), Distinguished Professor of Computing-based Society, and captain of science of Dutch Digital Delta, the Dutch top sector for missions and innovation in ICT.
- Prof. dr. Maarten de Rijke, University Professor of Artificial Intelligence and Information Retrieval at the University of Amsterdam, and scientific director of the national Innovation Center for Artificial Intelligence;
- Prof. dr. Bo Wahlberg, professor of Chair in Automatic Control at KTH Royal Institute of Technology; Sweden;
- Ir. Wietske Rem (student member), alumna Mechanical Engineering, Universiteit Twente.

The programme prepared a report on the implemented improvement plan. This report was made available to the panel members and secretary in preparation of the online visit. Prior to the visit, the panel studied this report as well as a number of supporting documents (see appendix 2).

Online site visit

On 15 September 2023, the MSc AI&ES was assessed in an online site visit by the panel to determine whether the programme had fulfilled the conditions imposed in the initial assessment. The panel discussed its findings based on the documentation, and had the opportunity to ask additional questions to programme representatives. This option was not used. It then reported its conclusions and findings to the programme management.

Report

After the online site visit, the secretary composed a draft report in consultation with the panel and sent it to the programme in order to have it checked for factual irregularities. The secretary discussed the ensuing

comments with the panel chair, and changes were implemented accordingly. The panel then finalised the report, and the secretary sent it to the TU/e.

Information on the programme

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

Programme name:	Artificial Intelligence & Engineering Systems
CROHO number:	66476
Level:	master
Orientation:	academic
Number of credits:	120 EC
Specialisations or tracks:	High-tech systems and robotics
	Mobility
	Healthcare
	Smart cities
	Science and discovery
	Manufacturing systems
Location:	Eindhoven
Mode(s) of study:	Fulltime
Language of instruction:	English
Submission date NVAO (assessment of conditions):	20-12-2023

Description of the assessment

Introduction

The master's programme AI&ES was assessed by an external panel on 22 October 2021 seeking initial accreditation. The panel advised the NVAO to conditionally accredit the programme due to an issue it encountered in the alignment of ILOs and courses concerning standard 2 (Teaching-Learning Environment). It posed the following conditions with regard to Standard 2 of the assessment framework (Teaching-Learning Environment):

> "The programme should strengthen alignment between courses and ILOs to ensure that the various components of the programme contribute to achieving its aims and build on the added value of bringing all disciplines within one master programme."

In order to implement this condition, the panel suggested the following actions:

1. Clarifying the position, overlap and complementarity of the individual tracks relative to each other and relative to the AI discipline at large, paying specific attention to the aims and focus of the AI Foundation and Science Track;
2. Aligning the tracks accordingly so that the intended multidisciplinarity can be maximally achieved both in the current Team project (creating mixed disciplinary teams) and elsewhere in the curriculum;
3. Optimizing the balance between coherence and flexibility in individual study paths (currently, the student's course selection can vary widely, making the programme very heterogeneous, while at the same time students select a track very early on in the programme, making it quite rigid);
4. Creating a process for constructively including feedback and lessons learned into adaptations of the design of the programme in the coming years;
5. Formally adopting the draft teaching and examination regulations and the composition of the examination board.

The Board of the NVAO adopted this condition and granted the MSc AI&ES conditional accreditation on 20 December 2021. Directly after the initial accreditation, the programme started taking actions for improvement, and used the first year of the programme (2022-2023) to observe and steer the results of these actions, and to optimize the curriculum. The programme management composed an overview of all developments and actions taken since the initial accreditation, structured alongside the five suggested actions, and provided this to the panel. This report uses this overview as the basis for an assessment of the condition imposed by the previous assessment panel.

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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

<u>Action 1: Tracks</u>

Clarifying the position, overlap and complementarity of the individual tracks relative to each other and relative to the AI discipline at large, paying specific attention to the aims and focus of the AI Foundation and Science Track.

During the 2021 assessment, the panel found that the alignment of the individual tracks with the programme's overall goal could be improved. The programme struggled to bring the tracks together under a common vision for the programme and with regard to its position in the AI discipline in general. The programme took this as an incentive to further develop its vision for the MSc AI&ES. It started by further analysing its intended learning outcomes in the light of the Dutch framework for AI master's programmes (KION Framework of Reference). The programme concluded the AI&ES provides students with both core and specialized knowledge in AI and engineering systems. The core knowledge is embedded in the common and track-specific core courses, and encompasses most of the KION criteria, with the exception of those related to the fundamentals of AI (Cognitive Science and Computational Linguistics). In all courses, AI is taught in relation to engineering systems, building on the engineering background of students. As such, the programme can be defined as being on the interface between engineering systems and AI. Specialized knowledge is provided in the tracks. Students are taught to use AI to study engineering challenges within the application domain of the track. Overall, the vision of the programme is to educate engineers in a specific engineering application domain at the interface between engineering systems and AI.

Using this strengthened vision, the programme revised the track structure to ensure that students in all tracks are able to obtain the required knowledge described in the programme vision. The programme introduced four themes (domain-specific knowledge, AI in Engineered Systems, Data Cultivation, and Learning & Intelligence) that are required to be present in the core courses in each of the tracks. The ILOs of the programme, including those of the individual tracks, were adjusted to reflect these new themes. This means that all students encounter core AI knowledge and skills in a similar fashion in the curriculum, regardless of the track they are in. Furthermore, the list of track-specific specialization courses was revised to provide more focus towards the domain covered by the track. The programme management decided to make this revision a yearly exercise, in order to keep the content of the specializations up-to-date. Finally, the programme introduced several manuals and guidelines to promote coherence between courses and tracks, including manuals for the Interdisciplinary Team Project and the graduation project, and a centralized database for all graduation projects.

The panel studied the new programme vision as well as the new curriculum structure. It thinks that the vision is coherent and fits the character of the AI&ES programme. The clarification of the programme's position within the AI landscape is appropriate, with a clear choice not to cover the fundamentals of AI (Cognitive Science and Computational Linguistics), as this does not fit the programme vision to teach AI in relation to engineering applications. Furthermore, the vision has been implemented in the intended learning outcomes as well as in the curriculum in an insightful way. The panel concludes that the programme now has a

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coherent common core that is the same for students. The new track structure makes the tracks more comparable in terms of content, organization and procedures, making the curriculum overall much more coherent. Finally, the panel noted with appreciation that the Human-AI Interaction and Ethics pillar has been positioned more explicitly in the curriculum, and is now present in all tracks.

In the redesign of the curriculum, the MSc paid specific attention to the track AI Foundation and Science. In 2021, the panel found this track found to be different in set-up from the other tracks, focusing on foundations rather than a specific application domain. The track was evaluated by the programme management with all involved coordinators and lecturers. As a result, the focus of the track was shifted to highlight the role of AI in scientific discovery in engineering domains such as materials design, fluid dynamics and decision-making in complex engineering systems. The track name has been adapted to 'Science and Discovery' to remove the association with the computer science foundations of AI, which are not intended to be the focus of the track. The panel thinks that this change in focus better fits the overall programme vision, and thinks that this track is now in line with the other tracks in terms of application domains.

Action 2: Multidisciplinarity

Aligning the tracks accordingly so that the intended multidisciplinarity can be maximally achieved both in the current Team project (creating mixed disciplinary teams) and elsewhere in the curriculum.

During the initial accreditation, the panel felt that multidisciplinarity in the curriculum could be improved, as several courses (particularly the specialization courses) still had a predominantly disciplinary focus. It suggested increasing opportunities for collaboration between students of the different tracks, for instance in the Interdisciplinary Team Project, where students apply their knowledge to a real-life case. After the initial accreditation, the AI&ES director launched a workgroup to address the implementation of multidisciplinarity in the curriculum. Several experts external to the MSc advised the programme on how to best implement the panel recommendations. The entire teaching staff of the programme participated in sessions and workshops to discuss current and future elements of multidisciplinarity in AI&ES.

The resulting alignment of the curriculum with the multidisciplinarity goals of AI&ES has the following elements. The curriculum starts in the first year by making students aware of and acquainted with multidisciplinarity in the courses. The core course Data Science has an introductory workshop on the topic, and courses offer multiple perspectives on topics from different disciplines. This is often achieved by teaching teams of lecturers with different backgrounds. Furthermore, students from different disciplines collaborate on assignments aimed at integration of scientific knowledge in the use of AI. Further awareness for this is created in a second workshop as part of the core course Data Acquisition and Analysis. The Interdisciplinary Team Project is considered to be the cornerstone of multidisciplinarity in the curriculum. Each track organizes interdisciplinary projects, often with industry, where students work on a challenge that requires knowledge and skills from different disciplines. The programme composes the student teams in such a way that different BSc backgrounds are represented in the teams. Students are prepared for this project by a skills training on 'Intercultural and Interdisciplinary Collaboration', offered as part of the professional skills training in the project course. Multi- and interdisciplinary collaboration is an explicit assessment criterion in the project assessment.

To further integrate this approach in the programme, the general programme ILOs have been adapted to emphasize the role of multi- and interdisciplinarity in the MSc. At the end of the first year, the first cohort of students (2022-2023) was interviewed in a focus group on the perceived multidisciplinarity in the first year of AI&ES. They recognized multidisciplinarity both in the courses and in the assignments, and appreciated this

as a key element relevant to real-life practice. Further planned improvements in the coming year are the consolidation of a learning line on multi- and interdisciplinarity on a programme level, organizing colloquia and activities with external stakeholders aimed at broadening the view of students on applying AI in multiple disciplines, and continuous improvement of courses on this aspect based on student feedback.

The panel applauds the thorough process through which the programme has increased attention to multidisciplinarity in the curriculum, and the resulting actions. It appreciates the involvement of many internal and external stakeholders, and the adaptations on all levels, from ILOs and course content to evaluation and assessment. This thorough approach even led to an education-oriented publication. The resulting curriculum convincingly takes away the initial concerns of the panel in 2021 and even surpasses expectations with a rich palette of multidisciplinary educational activities in all of the tracks.

The recommendation of the panel to mix student teams of different tracks in the Interdisciplinary Team Projects was not adopted by the programme, with the explanation that the programme considers all tracks to be interdisciplinary in themselves. Furthermore, the Team Projects are instrumental in giving students the opportunity to work on challenges within their own application domain, which would not be possible in track-overarching project groups. By mixing students with different BSc backgrounds in project groups, the programme aims to achieve multidisciplinarity within the track. The panel appreciates this clarification, and in this light fully understands this choice. As a side note, the panel noted that there are major differences in the popularity of the tracks, from 28 students in High Tech Systems and Robotics to 2 in the Science and Discovery track. During the feedback session with the programme it became evident that students from 'small' tracks participated in Team Projects of the most suited alternative track to obtain the interdisciplinary learning goals.

Action 3: Curriculum flexibility

Optimizing the balance between coherence and flexibility in individual study paths (currently, the student's course selection can vary widely, making the programme very heterogeneous, while at the same time students select a track very early on in the programme, making it quite rigid).

During the initial accreditation in 2021, the panel felt that the curriculum was both flexible in the sense that students have many different options to choose from, and on the other hand rigid in the sense that students already have to choose a track during admission to the programme. It recommended the programme to reflect on this.

The programme discussed the panel concerns and sought a way to increase both coherence and flexibility in the curriculum. In this endeavour, the programme was bound by the requirements posed by the TU/e Graduate School concerning the EC for core courses, specialization and electives. The programme decided to move all mandatory core courses to the first quartile, and the restricted-choice core courses to the second and third quartile. This allows for postponing the track choice to the second quartile, so that students can use their experience with the core courses to make their choice. The coupling between the choice of core courses and the graduation project, that was part of the initial curriculum design, has been dropped to allow students more flexibility in orienting themselves towards a choice of track and graduation project. In addition, a Choose Your Track event is organized at the start of the first year, where students can inform themselves on the different options. The programme has also formulated a procedure for changing tracks in case the student wants to, and established this in the Teaching & Examination Regulations.

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The panel studied the new curriculum structure as well as the measures taken to streamline the student's choice for a track. It appreciates that the curriculum is now much more flexible. Students are given time until the second quarter to choose a tracks. Now that the content of the tracks has been made more uniform (see also Action 1), a relatively seamless transition to another track is even possible after the second quartile. The event organized to inform students on the track options is a good addition to further assist students in making their choice. Finally, disconnecting the choice of core courses from the topic of the graduation project also allows students more time to orient themselves towards a topic for their project. The panel concludes that the programme convincingly implemented the action on curriculum flexibility suggested by the panel in 2021.

Action 4: Feedback cycle

Creating a process for constructively including feedback and lessons learned into adaptations of the design of the programme in the coming years.

The quality assurance procedures to collect and use feedback on the new programme were still under development at the time of the initial accreditation. Over the past two years, the programme has worked on constructing a feedback cycle for the MSc AI&ES. On top of the regular university and department-wide quality assurance structures, the programme management has organized a student survey followed by a feedback session two months after the start of the academic year 2022-2023 to discover any issues with the new programme. Independent from the programme management, the Student Body (SB) of the Electrical Engineering department, that houses AI&ES, also organized several student feedback sessions. These included questions on whether students felt they had sufficient prior knowledge, and if they felt all courses were relevant to the overall programme. On the lecturer side, all lecturers are asked about their experience with a course after each quartile. Furthermore, monthly track coordinator meetings have been introduced, where the six track coordinators exchange ideas and issues regarding the curriculum. These surveys and meetings did not bring any major shortcomings to light, but provided many ideas and insights to improve the courses and alignment between courses for the coming years. These include paying attention to the scheduling of electives as well as issues with prior knowledge regarding programming that some students reported.

The panel studied the feedback cycles implemented by the programme and concludes that the programme addressed this action in an excellent way. The documentation described multiple layers of quality assurance, providing students with multiple ways to provide their feedback on the programme. The planned and implemented changes to the curriculum based on student feedback show that the programme management is taking this feedback very seriously. The panel also valued that the feedback cycles actively involve the teaching staff as participants and not only objects of student feedback. Finally, the panel encourages the programme to implement the plans currently under development to also involve the regional industry in providing feedback to the programme.

Action 5: Examination

Formally adopting the draft teaching and examination regulations and the composition of the examination board.

Both formal requirements regarding examination have been adopted by the programme. The Examination Committee has been installed per the academic year 2022-2023, consisting of representatives of six participating departments as well as an external member. The exam regulations (Program and Examination

Regulations and the Regulations of the Examination Committee) have been formally approved for 2022-2023. At the time of the panel meeting, the 2023-2024 version had also been approved. The panel concludes that both requirements have adequately been implemented.

Considerations

The panel concludes that the MSc AI&ES has convincingly strengthened the alignment between the programme aims and the curriculum. The programme's vision and aims have been further developed and strengthened, and translated into a coherent curriculum in which the tracks all contribute to the realization of the programme's ILOs in a comparable way. The introduction of four themes in the core elements of the curriculum safeguards that students encounter relevant knowledge and skills in AI and engineering systems in a comparable way. The design of the tracks has been adjusted in such a way that they are much more coherent in terms of content, organization and procedures. Their set-up now follows naturally from the programme's vision to offer specialization within a specific application domain. The AI Foundation and Science track has been renamed and redesigned into a Science and Discovery track, making it comparable in set-up with the other tracks. The new curriculum structure and the alignment of the tracks also allow postponing the choice of a track until later in the first year. Multidisciplinarity has been strengthened in an impressive way in the entire curriculum in a thorough process that includes many internal and external stakeholders, turning it from a concern into a strength of the programme.

Overall, the panel is convinced that the programme has taken the advice and suggestions from the initial accreditation to heart. It has responded constructively, using input from relevant stakeholders resulting in solid educational practices. The condition and its actions as well as additional recommendations on for instance the feedback cycle and examination were extensively addressed, leading to the necessary changes to the teaching-learning environment.

Conclusion

The panel concludes that the programme has fulfilled the condition set for accreditation, and now meets standard 2 in addition to the other standards determined in the initial assessment.

General conclusion

The panel's assessment of the master's programme Artificial Intelligence & Engineering Systems is positive.

Appendix 1: Materials

The panel considered the following materials:

- Report for the re-assessment of the master AI & ES
- EAISI Mission & Vision document
- TU/e Vision On Education
- KION Frame of Reference 2018
- Teaching and Exam Regulations AI&ES 2022-2023 and 2023-2024
- Course information Interdisciplinary Team Project
- Study guide Graduation project AI&ES
- Assessment rubrics
- Information AIES Workshop Multidisciplinarity
- Guideline Graduate School 2021
- Information Track selection in the MSc AIES
- MSc AIES to-do list for students starting per September 2022
- TU/e Education Quality Assurance Framework
- QA Plan EE 2022-2023
- Report AI&ES Survey 2022
- Report Results Midterm Evaluation ITP