

Assessment report
Limited Framework Programme Assessment

Master Applied Mathematics

University of Twente

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1. Executive summary

In this executive summary, the panel presents the main considerations which led to the assessment of the quality of the Master Applied Mathematics programme of University of Twente. The programme was assessed according to the standards of the limited framework, as laid down in the NVAO Assessment framework for the higher education accreditation system of the Netherlands, published on 20 December 2016 (Staatscourant nr. 69458).

The panel appreciates the programme objectives to educate students in-depth in mathematics and the application of mathematics in societal and multidisciplinary contexts. The panel is positive about students acquiring research skills, modelling knowledge and skills and academic skills in this domain. The panel is pleased to note that the programme is strongly research-based.

The panel considers the Domain-Specific Framework of Reference to be an appropriate description of the mathematics discipline and of the standards and requirements graduates of both bachelor and master programme have to meet. The panel welcomes the efforts of the joint Mathematics programmes in the Netherlands to have drafted this Framework. The objectives and intended learning outcomes of this programme meet the Framework and, therefore, correspond to international standards set for the discipline.

The panel welcomes that students are being prepared for both academic and professional careers. The panel appreciates the options being offered to students, being the specialisations, the double master programmes and the programme to qualify as fully-qualified teachers in Mathematics in secondary education.

The intended learning outcomes of the programme correspond to the programme objectives, are comprehensive and are conform to the master level.

The panel approves of the entry requirements and admission procedures of the programme. Students are informed about the programme and are guided appropriately at the start of the curriculum.

The curriculum of the programme matches the intended learning outcomes. The panel considers the contents of the curriculum to be appropriate, students being introduced to the fundamentals of applied mathematics and being taught one of the specialisations offered. The panel appreciates the Pioneers of Applied Mathematics course, acquainting students with historical, societal and ethical dimensions of the discipline. The curriculum coherence is up to standard, as students are guided by chair holders to draft their study plans. Research skills are addressed prominently in the curriculum. Mastermath is also positively regarded, as it offers a wide range of courses in various fields to students at a high level. As some of these courses may have become more challenging, the panel suggests to discuss this with Mastermath management.

The staff lecturing in the programme have solid research backgrounds and are skilled and motivated teachers. Their educational capabilities are up to standard. The panel notes the high level of appreciation of lecturers by students. The work load of lecturers is high but manageable. The panel is pleased to see that extra staff is recruited. The panel is positive about educational capabilities being part of the recruitment procedures of staff, suggesting to maybe add test lectures.

The panel is positive about the educational concept and study methods of the programme. The study load is appropriate. The panel appreciates the student guidance in the programme, both by the chair holders and by the study advisor. The material facilities for the programme are up to standard. The drop-out rates and the student success rates of the programme are adequate.

The examination and assessment policies for the programme are appropriate. The panel regards the Examination Board as being professional in executing its duties. The panel welcomes the measures taken by programme management to ensure the examinations and assessments quality. The panel approves of the quality control of the Mastermath examinations by the Examination Board.

The examination methods selected in the courses are approved by the panel, these matching the course contents. The supervision and assessment procedures for the Internship are up to standard.

The Master Project assessment and supervision processes are organised reliably and effectively. The panel, however, advises to add more extensive arguments to substantiate the assessments of these final projects.

The examinations of the courses are adequate. The Master Projects are appropriate. Master Projects vary in terms of quality and level. The panel supports the grades awarded to the projects by the programme examiners. No projects were found to be unsatisfactory. The panel agrees that the *cum laude* requirements are being made more strict by the programme.

The panel assesses that the programme graduates have reached the intended learning outcomes of the programme. The panel suggests to strengthen the relations with the programme alumni.

The panel that conducted the assessment of the Master Applied Mathematics programme of University of Twente assesses this programme to meet the standards of the limited framework, as laid down in the NVAO Assessment framework for the higher education accreditation system of the Netherlands, judging the programme to be *satisfactory*. Therefore, the panel recommends NVAO to accredit this programme.

Rotterdam, 23 September 2019

Prof. dr. ir. O.J. Boxma
(panel chair)

drs. W. Vercouteren
(panel secretary)

2. Assessment process

The evaluation agency Certiked VBI received the request by University of Twente to support the limited framework programme assessment process for the Master Applied Mathematics programme of this University. The objective of the programme assessment process was to assess whether the programme conforms to the standards of the limited framework, as laid down in the NVAO Assessment framework for the higher education accreditation system of the Netherlands, published on 20 December 2016 (Staatscourant nr. 69458).

Management of the programmes in the assessment cluster WO Wiskunde convened to discuss the assessment panel composition and to draft the list of candidates. The panel composition for this assessment has been based upon these considerations.

Having conferred with University of Twente programme management, Certiked invited candidate panel members to sit on the assessment panel. The panel members agreed to do so. The panel composition was as follows:

- Prof. dr. ir. O.J. Boxma, full professor Stochastic Operations Research, Eindhoven University of Technology (panel chair);
- Prof. dr. R.H. Kaenders, full professor Mathematics and its Education, University of Bonn, Germany (panel member);
- Prof. dr. D. van Straten, full professor Algebraic Geometry, Johannes Gutenberg University Mainz, Germany (panel member);
- Dr. ir. H.J. Prins, manager Research & Development, Maritime Research Institute the Netherlands (panel member);
- S.R. den Breeijen MSc, recently graduated student Master Mathematics, Radboud University Nijmegen (student member).

On behalf of Certiked, drs. W. Vercouteren served as the process coordinator and secretary in the assessment process.

All panel members and the secretary confirmed in writing being impartial with regard to the programme to be assessed and observing the rules of confidentiality. Having obtained the authorisation by the University, Certiked requested the approval of NVAO of the proposed panel to conduct the assessment. NVAO have given their approval.

To prepare the assessment process, the process coordinator convened with management of the programme to discuss the planning of the activities in preparation of the site visit. The site visit schedule was also discussed. In addition, the outline of the self-assessment report and the subjects to be addressed in this report were part of the discussion.

In the course of the process preparing for the site visit, programme management and the Certiked process coordinator had contact to fine-tune the process. The activities prior to the site visit have been performed as planned. Programme management approved the site visit schedule.

Well in advance of the site visit date, programme management sent the list of final projects of graduates of the programme of the most recent years. Acting on behalf of the assessment panel, the process coordinator selected the final projects of fifteen graduates of these years. The grade distribution in the selection was conform to the grade distribution in the list, sent by programme management. The specialisations are covered in the selection.

The panel chair and the panel members were sent in time the self-assessment report of the programme, including appendices. In the self-assessment report, the student chapter was included. In addition, the expert panel members were forwarded a number of theses of the programme graduates, these theses being part of the selection made by the process coordinator.

Before the site visit date, the assessment panel chair and the process coordinator met to discuss the self-assessment report to be provided by programme management, the procedures regarding the assessment process and the site visit schedule. In this meeting, the profile of panel chairs of NVAO was discussed as well. The panel chair was comprehensively informed about the competencies, listed in the profile.

Being informed by the process coordinator, all panel members sent in their preliminary findings, based on the self-assessment report and the final projects studied, and a number of questions to be put to the programme representatives on the day of the site visit. The panel secretary summarised this information, compiling a list of questions, which served as a starting point for the discussions with the programme representatives during the site visit.

Shortly before the site visit date, the panel met to go over the preliminary findings concerning the quality of the programme. During this meeting, the preliminary findings of the panel members, including those about the theses were discussed. The procedures to be adopted during the site visit, including the questions to be put to the programme representatives on the basis of the list compiled, were discussed as well.

On 12 July 2019, the panel conducted the site visit on the University of Twente campus. The site visit schedule was as planned. In a number of separate sessions, the panel was given the opportunity to meet with Faculty Board representatives, programme management, Examination Board members, lecturers and final projects examiners, and students and alumni.

In a closed session near the end of the site visit, the panel considered every one of the findings, weighed the considerations and arrived at conclusions with regard to the quality of the programme. At the end of the site visit, the panel chair presented a broad outline of the considerations and conclusions to programme representatives.

Clearly separated from the process of the programme assessment, the assessment panel members and programme representatives met to conduct the development dialogue, with the objective to discuss future developments of the programme.

The assessment draft report was finalised by the secretary, having taken into account the findings and considerations of the panel. The draft report was sent to the panel members, who studied it and made a number of changes. Thereupon, the secretary edited the final report. This report was presented to programme management to be corrected for factual inaccuracies. Programme management were given two weeks to respond. Having been corrected for these factual inaccuracies, the Certiked bureau sent the report to the University Board to accompany their request for re-accreditation of this programme.

3. Programme administrative information

Name programme in CROHO: M Applied Mathematics
Orientation, level programme: Academic Master
Grade: MSc
Number of credits: 120 EC
Specialisations: Operations Research
Mathematical Systems Theory, Applied Analysis and Computational
Science
Mathematics of Data Science
Location: Enschede
Mode of study: Full-time
Language of instruction: English
Registration in CROHO: 21PH-60348
Name of institution: University of Twente
Status of institution: Government-funded
Institution's quality assurance: Approved

4. Findings, considerations and assessments per standard

4.1 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.

Findings

The Master Applied Mathematics programme is one of the programmes of the Faculty of Electrical Engineering, Mathematics and Computer Science of University of Twente. The Faculty Steering Committee Education, chaired by the Portfolio Holder Education, has the responsibility for the organisation and the quality of this and the other programmes of the Faculty. The director of this programme, assisted by the master coordinator and the study advisor, is responsible for the organisation and delivery of this programme. Lecturers are members of the Department of Applied Mathematics of the Faculty. They do not only lecture in this programme, but are also engaged in service education for other programmes of University of Twente. The Programme Committee, consisting of an equal number of lecturers and students, advises programme management on quality issues regarding the programme. The Examination Board for both the Bachelor and Master Applied Mathematics programmes is responsible for assuring the quality of examinations and assessments of these programmes. This Examination Board is part of the Faculty-wide Examination Board.

The objectives of the programme are to educate students in applied mathematics, i.e. students having the knowledge and skills to apply mathematics in societal and multidisciplinary contexts. Students are educated in research skills, knowledge of and skills in mathematical modelling, professional skills, academic reflection competencies and communication skills. The programme is strongly research-based, the subjects and topics taught being based upon research done in these fields.

The joint Mathematics programmes in the Netherlands drafted the Domain-Specific Framework of Reference for Bachelor and Master Mathematics programmes. In this Domain-Specific Framework of Reference, the generic objectives and the generic intended learning outcomes for these programmes have been listed. These objectives and intended learning outcomes meet the international standard for mathematics of ASIIN in Germany. They also correspond to the Dublin descriptors and the Meijers' criteria. In addition, they are largely comparable to those of the Mathematics programmes of renowned universities abroad, as ETH Zürich, KU Leuven and University of Padova.

The programme offers three specialisations. These are Operations Research; Mathematical Systems Theory, Applied Analysis and Computational Science; and Mathematics of Data Science. The Operations Research specialisation is directed towards the study of optimisation problems. The Mathematical Systems Theory, Applied Analysis and Computational Science specialisation addresses numerical methods, mathematical modelling or systems and control. The Mathematics of Data Science specialisation is geared to the study of mathematical models and algorithms to analyse data and to derive decisions from these. All specialisations originate from research done in the Department of Applied Mathematics and are intimately connected to specific research groups (chairs) within this Department.

In addition to taking the general programme, students may take double Master programmes combining Applied Mathematics with, among others, Applied Physics, Technical Computer Science or Technical Medicine. Students may also combine this programme and the Science Education and Communication programme, preparing them to become fully-qualified teachers in Mathematics in secondary education. Lastly, students are allowed to take the Double-degree programme, jointly offered by University of Twente and Universitas Gadjah Mada in Indonesia.

Students are educated to enter the labour market and to find positions both in academia and in the professional field.

The objectives of the programme have been translated into the intended learning outcomes for the programme. These include, as main elements, in-depth knowledge and understanding of mathematics and the application of mathematics in various areas; knowing how to address complex mathematical research questions; knowing how to apply mathematical methods and techniques to different areas of application; communication skills; and awareness of applied mathematics' societal position and ethical dimensions.

The intended learning outcomes of the programme have been compared to the Meijers' criteria for master programmes, to establish their master level.

Considerations

The panel appreciates the programme objectives to educate students in-depth in mathematics and the application of mathematics in societal and multidisciplinary contexts. The panel is positive about students acquiring research skills, modelling knowledge and skills and academic skills in this domain. The panel is pleased to note that the programme is strongly research-based.

The panel considers the Domain-Specific Framework of Reference to be an appropriate description of the mathematics discipline and of the standards and requirements graduates of both bachelor and master programme have to meet. The panel welcomes the efforts of the joint Mathematics programmes in the Netherlands to have drafted this Framework. The objectives and intended learning outcomes of this programme meet the Framework and, therefore, correspond to international standards set for the discipline.

The objectives of the programme to prepare students for both academic and professional careers are welcomed by the panel. The panel appreciates the specialisations offered, allowing students to select areas of their preference. The panel also welcomes that students are offered opportunities to take double master programmes and to qualify as fully-qualified teachers in Mathematics in secondary education.

The intended learning outcomes of the programme correspond to the programme objectives. These intended learning outcomes are comprehensive and are conform to the master level.

Assessment of this standard

These considerations have led the assessment panel to assess standard 1, Intended learning outcomes, to be satisfactory.

4.2 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.

Findings

The number of students entering the programme remained rather stable over the years, going from 23 incoming students in 2013 to 25 students in 2018. The average intake in the programme is 25 students over the last six years. The number of foreign students is relatively limited. The number of students taking double master programmes or preparing for careers as teachers is quite limited as well. Students having completed the Bachelor Applied Mathematics programme at one of the Dutch Universities of Technology are admitted unconditionally. Students with bachelor degrees in other disciplines may be admitted directly or after having taken the pre-master programme (maximum 30 EC). All admission requests are reviewed to see whether applicants may be able to complete the programme and to do so within two years. The programme schedules a number of events to inform prospective students about the programme. Upon enrolment, the master coordinator advises students on their study schedule in the first quarter. Having enrolled, students are to choose their specialisation. They meet with the chair holder of the research group being responsible for the specialisation to draft their study plans.

The study load of the curriculum is 120 EC. The curriculum takes two years to complete. Programme management presented a table, mapping the intended learning outcomes to the curriculum components. The curriculum consists of compulsory core courses (17 EC), specialisation-specific courses (15 EC to 18 EC), elective courses (25 EC to 28 EC), Internship (20 EC), and Master Project (40 EC). The courses are scheduled in the first year, whereas the Internship and the Master Project are scheduled in the second year. The core courses are *Scientific Computing*, *Continuous Optimisation* and *Pioneers of Applied Mathematics*. These core courses cover essential elements for all specialisations. The Pioneers of Applied Mathematics course addresses historical, philosophical, societal and ethical aspects of applied mathematics. For the specialisation-specific courses, students have to select a number of courses from a list of constrained elective courses. These courses allow students to go in-depth into the specialisation subjects. In the Internship, students take on real-life problems in external organisations. The chair holder of the specialisation research group assures the academic level of the internship project. The Master Project (40 EC) is the final curriculum component, requiring students to conduct an individual research project. Students are obliged to take at least one Mastermath course. Most students take two or more Mastermath courses, mainly offered by one of the Universities of Technology.

The permanent staff members, lecturing in the programme, are nearly all active researchers in their fields, being members of the Department of Applied Mathematics and having obtained PhD degrees. Lecturers are involved in the research groups for the specialisations offered in the programme. About 82 % of the lecturers are UTQ-certified. The other lecturers are in the process of obtaining their UTQ-certificate. The lecturers are free in designing their courses, as long as they meet the learning goals of the courses. All staff come together twice per year to discuss the programme. Students appreciate lecturers' teaching skills, their accessibility and their readiness to help. The work load is experienced by the lecturers to be high but manageable. The Mathematics sector plan will allow the programme to recruit extra staff. In the recruitment processes of new staff members, the teaching capabilities of candidates are taken into account.

The educational concept of the programme is geared towards offering small-scale, research-based and intensive teaching. Study methods adopted in the courses are predominantly lectures. Tutorials or homework assignments are part of a number of courses. The chair holder of the research group for the specialisation and the master coordinator assist students in drafting their individual study plans and approve these plans. The study advisor monitors the study progress of students, and invites them to discuss study-related problems. The average drop-out rate is about 15 %, calculated for the last five years. The average student success rates are about 12 % after two years and about 70 % after three years (last two to three cohorts).

Considerations

The number of incoming students is adequate. The panel approves of the entry requirements and admission procedures of the programme. Students are informed about the programme and are guided appropriately at the start of the curriculum.

The curriculum of the programme matches the intended learning outcomes. The panel considers the contents of the curriculum to be appropriate, students being introduced to the fundamentals of applied mathematics and being taught one of the specialisations offered. The panel appreciates the Pioneers of Applied Mathematics course, acquainting students with historical, societal and ethical dimensions of the discipline. The curriculum coherence is up to standard, as students are guided by chair holders to draft their study plans. Research skills are addressed prominently in the curriculum. Mastermath is also positively regarded, as it offers a wide range of courses in various fields to students at a high level. As some of these courses may have become more challenging, the panel suggests to discuss this with Mastermath management.

The staff members lecturing in the programme have solid research backgrounds and are skilled and motivated teachers. Their educational capabilities are up to standard. The panel notes the high levels of appreciation of lecturers by students. The work load of lecturers is high but manageable. The panel is pleased to see that extra staff is recruited. The panel is positive about educational capabilities being part of the recruitment procedures of staff, suggesting to maybe add test lectures.

The panel is positive about the educational concept and study methods of the programme. The panel considers the study load to be appropriate. The panel appreciates the student guidance in the programme, both by the chair holders and by the study advisor. The material facilities for the programme are up to standard. The drop-out rates and the student success rates of the programme are adequate.

Assessment of this standard

These considerations have led the assessment panel to assess standard 2, Teaching-learning environment, to be satisfactory.

4.3 Standard 3: Student assessment

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

The rules and regulations for the programme examinations and assessments have been laid down in the programme assessment policy plan. The examinations and assessments are governed by the principle of constructive alignment, linking the course examinations to the learning goals and the contents of the courses. The rules and regulations are in line with the University of Twente assessment framework. The Examination Board has the authority to assure the quality of examinations and assessments of the programme. The Board is part of the Faculty-wide Examination Board. This Faculty-wide Board works on common rules and regulations for all programmes of the Faculty.

The examination methods in the courses are mainly written examinations. Other examination methods adopted are oral examinations or homework assignments. Internships are supervised by the internship supervisor, being one of the staff members of the research group for the specialisation. The supervisor assesses the internship on the basis of the written report and the interview with the student. For the assessment, the supervisor consults with the company supervisor about the performance of the student.

At the end of the curriculum, the Master Project is scheduled. Master Projects are individual research projects. Students are supervised in these projects by the supervisor from the research group for the specialisation. PhD students may be involved in the day-to-day supervision of students. Master projects are strictly scheduled, the deadline being set at the start of the project. The projects are assessed by the Assessment Committee, which is composed of at least two members. One of the members is the chair holder of the research group involved and one of the other members is the staff member of one of the other research groups. Members of the Examination Board may be present as well. For their assessment, they make use of the standardised assessment form. The assessment criteria are the scientific quality of the work, the research process, the written report and the oral presentation and defence.

In the programme, measures have been taken to ensure the validity, reliability and transparency of examinations and assessments. The Examination Board appoints examiners. Examination drafts are peer-reviewed by fellow examiners. Examinations are documented in course files. The Examination Board inspects course files. Students are presented test examinations and are allowed to inspect their marked work. The composition of the Assessment Committee for the Master Projects allows for the calibration of assessments and grades within research groups and across research groups. All written assignments, including the Master Projects are checked for fraud or plagiarism.

The Examination Board monitors the contents and quality of the Mastermath courses and examinations. Mastermath presents the course records, examination reports and the names of the examiners for the courses to the examination boards of the participating universities. These boards verify the quality of the courses and of the examinations. If one board, notably the board of the university offering the course, approves of the quality, the other boards accept this decision as their own. The examination boards of all programmes, participating in Mastermath, meet yearly to discuss the Mastermath examinations' and assessments' quality assurance. The Teaching and Examination Regulations of this University of Twente programme apply for the Mastermath courses.

Considerations

The panel considers the examination and assessment policies for the programme to be appropriate, these being in line with the University of Twente guidelines. The position and the authority of the Examination Board are adequate. The panel regards the Examination Board as being professional in executing its duties.

The examination methods selected in the courses are approved by the panel, these matching the course contents. The supervision and assessment procedures for the Internship are up to standard.

The Master Project assessment and supervision processes are organised reliably and effectively. The panel, however, advises to add more extensive arguments to substantiate the assessments of these final projects. These may take the form of concise comments on the selection of the topic of the thesis, the preparation of the student on the subject concerned, the summary of the contents of the thesis, the specification of the own contributions by the student, the creativity and mathematical depth of the student contributions, and the quality of writing and oral presentation by the student.

The panel welcomes the measures taken by programme management to ensure the examinations and assessments quality. The panel considers these measures to be adequate and to promote valid, reliable and transparent examinations and assessments. The panel approves of the regulations regarding the Mastermath examinations and the quality control of these examinations by the Examination Board.

Assessment of this standard

The considerations have led the assessment panel to assess standard 3, Student assessment, to be satisfactory.

4.4 Standard 4: Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.
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Findings

The panel studied the examinations of a number of courses of the programme.

The panel reviewed the Master Projects of fifteen graduates of the programme with different grades and from different specialisations. The projects are individual research projects in applied mathematics, being geared towards the specialisations offered in the programme. In the Master Projects, students are to demonstrate having mastered nearly all of the intended learning outcomes of the programme. The average grade for these projects is 7.9 for the graduates of the last five years. About 26 % of the programme graduates of the last five years graduated *cum laude*. The programme regards this proportion as too high. The programme expects this figure to decrease the coming years, as measures have been taken to this effect (grade required for the Master Project has been raised from grade 8 to grade 9).

In the programme, students are getting acquainted with the professional field. All students do internships in industry, obtaining insights into the application of mathematics in the professional practice. Some of the Master projects are being designed and executed in collaboration with industry.

The programme conducted a survey among programme alumni. The results from this survey reveal that students are generally very content about the programme. Programme graduates are employed by industrial companies, engineering or general consultancies, financial or insurance companies or semi-governmental institutions. About 10 % of the programme graduates proceed to PhD trajectories. Some graduates work as teachers in secondary education.

Considerations

The examinations of the courses which were reviewed by the panel are adequate.

The Master Projects, studied by the panel, are appropriate. The level reached by students is adequate. Master Projects vary in terms of quality and level. The panel supports the grades awarded to the projects by the programme examiners. No projects were found to be unsatisfactory. The panel agrees that the *cum laude* requirements are being made more strict by the programme.

The panel assesses that the graduates have reached the intended learning outcomes of the programme. Programme graduates obtain positions at academic level in a range of organisations. The panel suggests to strengthen the relations with the programme alumni.

Assessment of this standard

The considerations have led the assessment panel to assess standard 4, Achieved learning outcomes, to be satisfactory.

5. Overview of assessments

Standard	Assessment
Standard 1. Intended learning outcomes	Satisfactory
Standard 2: Teaching-learning environment	Satisfactory
Standard 3: Student assessment	Satisfactory
Standard 4: Achieved learning outcomes	Satisfactory
Programme	Satisfactory

6. Recommendations

In this report, a number of recommendations by the panel has been listed. For the sake of clarity, these have been brought together below.

- To discuss with Mastermath management that some Mastermath courses are becoming more and more challenging.
- To add more extensive comments and arguments to substantiate the assessments of the Master Projects.
- To strengthen the relations with programme alumni.