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MSc Systems Biology
Maastricht University

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Project code P2114

Contents

Summary

The MSc Systems Biology is a 120 EC master's programme offered by the Faculty of Science and Engineering (FSE) of Maastricht University (UM), aimed at providing students with knowledge and skills to connect mathematics and biology. The profile and aims of the master's programme Systems Biology are fitting for an academic programme within the field. The programme has a strong interdisciplinary character and meets the demand from academia and industry for students that can connect biology and mathematics. The programme is embedded in the MaCSBio research centre, giving the programme a strong biomedical profile. The panel recommends making this more explicit in the profile and aims. Furthermore, the panel recommends focusing more on non-academic careers for its graduates, as it expects that demand from both students and industry will grow in this regard. The goals of the programme have been well-translated into a coherent set of intended learning outcomes that are aligned with the Dublin descriptors for master's programmes. The panel recommends updating the ILOs to reflect the high level that students achieve in for instance creation and evaluation skills and formulating the level that all students should achieve in the various disciplines that contribute to the interdisciplinary field of systems biology.

The master's programme Systems Biology has translated its intended learning outcomes into a well-structured and attractive curriculum. The Problem-Based Learning approach is clearly visible and well-suited to the small-scale and diverse character of the programme. The curriculum is well-balanced with regard to core courses, electives and projects. According to the panel, the core curriculum could be further improved by expanding attention to ethics, in particular with regard to handling medical data and ethical procedures for experimentation. The programme should also evaluate whether all students are sufficiently trained in scientific programming, dynamic modelling and the verification of hypotheses in research, and adapt the curriculum accordingly. The choice to offer the programme in English is well-supported and fits the international character of the field.

Students are very well supported throughout the programme, including during the COVID-19 pandemic. The admission procedure and the start of the programme helps students identifying and remedying any knowledge gaps, and students receive guidance to help them tailor the curriculum to their preference. This has translated into high student satisfaction and high success rates. Regarding the admission criteria, the panel recommends providing prospective students with more insight into the advisable level of biology, so they can improve their knowledge if they desire to do so. Furthermore, the panel considers the two fixed starting dates for the thesis to be rather strict and supports the initiatives to offer more flexibility in this regard.

The programme is taught by an enthusiastic and motivated teaching staff with a diversity of expertise relevant to the programme. The small-scale setting allows for close collaboration between staff and students, which is very much appreciated by both sides. The programme management is dedicated to the continuous development of the programme and has knowledge exchange and professionalization high on the agenda.

The programme has a valid, transparent and reliable system of assessment in place. The assessment methods are varied and fit the goals of the programme. Assessment in the programme is supported by solid quality assessment procedures and a well-functioning and proactive Board of Examiners. The programme successfully changed to online examination during the relatively short time this was required in the COVID-19 pandemic. To further improve the assessment system, the panel suggests adding assessment of code quality to the curriculum. Thesis assessment is well-designed, with an insightful and transparent assessment form

and much attention to feedback. The grading is transparent and valid but has a tendency to drift towards the high end of the spectrum. The panel supports the adjustments to the rubric aimed at recalibrating this.

The panel concludes that graduates of the programme achieve the intended learning outcomes. The theses are generally of very high quality, for which the panel praises the programme. Alumni find relevant positions after graduation and are in high demand.

Score table

The panel assesses the programme as follows:

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. Yves Moreau
Date: 10-03-2022

Peter Hildering MSc

Introduction

Procedure

Assessment

On 1 and 2 December 2021, the MSc Systems Biology of Maastricht University was assessed by an independent peer review panel as part of the cluster assessment Bioinformatics & Systems Biology. The assessment cluster consisted of 2 programmes, offered by Maastricht University and VU Amsterdam/ University of Amsterdam (joint degree). The assessment followed the procedure and standards of the NVAO Assessment Framework for the Higher Education Accreditation System of the Netherlands (September 2018).

Quality assurance agency Academion coordinated the assessment upon request of the cluster. Peter Hildering MSc acted as coordinator and secretary in the cluster assessment. He has been certified and registered by the NVAO.

Preparation

Academion composed the peer review panel in cooperation with the institutions and taking into account the expertise and independence of the members as well as consistency within the cluster. On 13 October 2021, the NVAO approved the composition of the panel. The coordinator instructed the panel chair on his role in the site visit according to the Panel chair profile (NVAO 2016).

The programme composed a site visit schedule in consultation with the coordinator (see Appendix 3). The programme selected representative partners for the various interviews. It also determined that the development dialogue would take place after the site visit. A separate development report was made based on this dialogue.

The programme provided the coordinator/secretary with a list of graduates over the period 2016-2021. In consultation with the secretary, the panel chair selected 15 theses per programme. He took the diversity of final grades and examiners into account. Prior to the site visit, the programme provided the panel with the theses and the accompanying assessment forms. It also provided the panel with the self-evaluation report and additional materials (see Appendix 4).

The panel members studied the information and sent their findings to the secretary. The secretary collected the panel's questions and remarks in a document and shared this with the panel members. In a preliminary meeting, the panel discussed the initial findings on the self-evaluation report and the theses, as well as the division of tasks during the site visit. The panel was also informed on the assessment framework, the working method and the planning of the site visits and reports.

Site visit

The site visit was organized online because of COVID restrictions. During the site visit, the panel interviewed various programme representatives (see Appendix 3). The panel also offered students and staff members an opportunity for confidential discussion during an online consultation hour. No consultation was requested. The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the preliminary findings.

Report

The secretary wrote a draft report based on the panel's findings and submitted it to a colleague for peer assessment. Subsequently, the secretary sent the report to the panel for feedback. After processing this feedback, the secretary sent the draft report 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 finalized the report, and the coordinator/secretary sent it to the Faculty of Science and Engineering of Maastricht University.

Panel

The following panel members were involved in the cluster assessment:

- Prof. dr. Yves Moreau (KU Leuven) - chair
- Prof. dr. Barbara Bakker (UMC Groningen)
- Dr. Jildau Bouwman (TNO)
- Dr. Sonja Isken (Wageningen University & Research)
- Dr. Peter Reinink (Gadeta BV)
- Claudia de Buck, BSc (Wageningen University & Research) - student member

The panel assessing the MSc Systems Biology at Maastricht University consisted of the following members:

- Prof. dr. Yves Moreau (KU Leuven) - chair
- Prof. dr. Barbara Bakker (UMC Groningen)
- Dr. Jildau Bouwman (TNO)
- Dr. Sonja Isken (Wageningen University & Research)
- Claudia de Buck, BSc (Wageningen University & Research) - student member

Information on the programme

Name of the institution:	Maastricht University
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive
Programme name:	Systems Biology
CROHO number:	60956
Level:	Master
Orientation:	Academic
Number of credits:	120 EC
Specializations or tracks:	-
Location:	Maastricht
Mode(s) of study:	Fulltime
Language of instruction:	English
Submission date NVAO:	01-05-2022

Description of the assessment

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

Aims and profile

The MSc Systems Biology is a 120 EC-master's programme offered by the Faculty of Science and Engineering (FSE) of Maastricht University (UM). It was initiated in 2015 with the aim to provide students with knowledge and skills to connect mathematics and biology. Students learn to extract biologically relevant information from data sets through modelling and analysis, and to design follow-up experiments. The field of systems biology departs from the insight that biological properties emerge from the complex interaction between multiple elements, ranging from the level of molecules to cells and even entire organisms. Students learn to reason about biological problems in mathematical terms, implement these in a computational form and use these insights for academic, industrial and societal progress. The programme is multidisciplinary, admitting students with backgrounds in biology, mathematics, data science, computer science and other natural science and technology focused BSc programmes.

The programme is embedded in the Maastricht Centre for Systems Biology (MaCSBio), a research centre established in 2015 that performs research in societally-relevant areas related to systems biology. The institute is a joint initiative of FSE, the Faculty of Psychology and Neurosciences (FPN) and the Faculty of Health, Medicine and Life Science (FHML), working on research related to chronic disease, neural and genetic systems and toxicology.

The panel studied the aims and profile of the programme and concludes that the programme has a clear and relevant profile. According to the panel, the programme meets a clear demand from academia and industry. Systems biology is a rapidly developing field, with a strong demand for students that can combine biology and mathematics in a computational approach. The embedding in MaCSBio provides the programme with a focus on biomedical applications related to human health and guarantees a strong embedding in state-of-the-art research in this area. The panel noted that students recognize this biomedical profile, and often specifically choose the programme for this reason. The panel thinks that this is a strength of the programme that could be made more explicit in its profile, as well as in communication, in order to interest more students in the programme.

Both students and staff indicate that the programme is primarily organized as a research master, focused on an academic career for graduates, even though options for students interested in industry are present. The panel understands this research focus based on the small-scale character of the programme and the embedding in a research environment. Nevertheless, the panel thinks that the programme, in line with its own aims, could include non-academic career options more prominently in its profile and aims. The demand from industry for graduates from this programme is growing, and particularly if the programme grows in future (see below), more students will be interested in these opportunities.

During the site visit, the panel and programme representatives discussed the MSc's potential for growth. The programme currently attracts approximately 15 students per year. The panel has the impression that more students could be interested in the programme and recommends working on the visibility and reputation of the programme. Making the abovementioned focus on biomedical applications more explicit could be a good starting point for this. Furthermore, the panel thinks that the programme could work on increasing intake from a larger variety of BSc programmes. The majority of students come from either an exact (computer science, mathematics) or a biomedical (biomedical sciences/engineering) background, or from a BSc in Liberal Arts and Sciences. The panel thinks that there is an opportunity for the programme to attract more students with backgrounds in biochemistry, biophysics and life sciences, and suggests the programme to investigate whether it can step up its efforts to recruit from such BSc programmes. If the programme decides to pursue further growth, the panel suggests accompanying this by a reflection on how to upscale from a small-scale to a larger programme. Growth can sometimes come sooner and swifter than expected, and the programme should be prepared for this.

Intended learning outcomes

The programme has summarized its aims in a set of 23 intended learning outcomes (ILOs) (see Appendix 1). The ILOs are structured along the five Dublin descriptors for master's programmes. The programme uses a domain-specific framework of reference to relate the competencies of graduates to the expectations of the academic fields. To further keep the programme aligned with the demands of the academic and professional field, the programme is advised by an external advisory board on a faculty level. The programme is currently composing a programme-specific advisory board that is expected to become active in 2022-2023. The panel studied the ILOs and concludes that they conform to a well-structured overview of the knowledge, skills and attitudes that students should attain throughout the programme. The ILOs align with domain-specific framework, thus demonstrating the competences required of a graduate in the field of systems biology. The input of the external advisory board, particularly the future programme-specific board, is valuable to keep the programme's ILOs attuned with external demands for graduates. The use of the Dublin descriptors in designing the ILOs guarantee that they meet the requirements for an academic master's programme with regard to level and orientation.

The panel noted that the programme is modest in its formulation of the ILOs: in practice it offers more skills to students than described in the learning outcomes. According to the panel, the programme could for instance also rightly claim to provide students with skills indicated in the Dublin Descriptors with creation (design, construct, compose) and evaluation (appraise, assess, judge). The panel recommends updating the ILOs in this regard. Furthermore, the panel recommends making the ILOs more explicit regarding the level required in the various disciplines and skills within in the multidisciplinary programme. This includes for instance biology, mathematics, programming skills and ethics. The programme should formulate what the minimum level is that all students should achieve in these fields, regardless of their background.

Considerations

The profile and aims of the master's programme Systems Biology are fitting for an academic programme within the field. The programme has a strong interdisciplinary character and meets the demand from academia and industry for students that can connect biology and mathematics. The programme is embedded in the MaCSBio research centre, giving the programme a strong biomedical profile. The panel recommends making this more explicit in the profile and aims. Furthermore, the panel recommends focusing more on non-academic careers for its graduates, as it expects that demand from both students and industry will grow in this regard. The goals of the programme have been well-translated into a coherent set of intended learning outcomes that are aligned with the Dublin descriptors for master's programmes. The

panel recommends updating the ILOs to reflect the high level that students achieve in for instance creation and evaluation skills and formulating the level that all students should achieve in the various disciplines that contribute to the interdisciplinary field of systems biology.

Conclusion

The panel concludes that the programme meets Standard 1.

Standard 2. Teaching-learning environment

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

Findings

Curriculum and didactic concept

The curriculum of the MSc Systems Biology (Appendix 2) consists of 24 EC in compulsory courses, 36 EC in electives, two research projects (6 EC each) and the master thesis (48 EC). In their first semester, students follow three compulsory courses that cover the core of the programme (Systems Biology, Modelling Biosystems and Experimental Design & Data Management), as well as a compulsory levelling course. Depending on their previous degree, they follow either a mathematical (Mathematics of Biological Systems) or a biological (Biology and Physiology) course. The second and third semesters are reserved for electives: students choose two courses out of a set of programme-specific electives. This allows students to tailor the programme to their individual interests. The first and second semesters are completed with an integrated research project, in which students conduct a small-scale research project in a professional environment, allowing them to develop research and teamwork skills. Students complete the programme with a 48 EC thesis, consisting of a 5 EC research proposal and a 43 EC research project, conducted individually under supervision of a researcher in one of the research groups associated with the programme, or (after approval by the Board of Examiners) at another research institution or in-company. The programme is offered in English, following the international character of the research field as well as the prospective academic or professional environment in which graduates can be expected to work.

In line with the overall didactic approach of Maastricht University, the programme embraces Problem-Based Learning (PBL). This approach is characterized by student-centred, small-group tutorials under supervision of a tutor. The core teaching staff of each course usually act as tutor, sometimes assisted by additional tutors for larger courses. Tutorials are often centred around real-life challenges, that students collectively study and explore. In the research projects, the programme uses the PBL-variant of Research-Based Learning (RBL), where students work on research challenges in cooperation with one of the research groups associated with the programme. The thesis is the culmination of RBL, where students further develop and apply the research skills accumulated in the courses and projects.

The panel studied the curriculum of the programme, as well as the content of several courses, and discussed them with the programme management, students and teaching staff. It concludes that the programme's ILOs are well-incorporated in the curriculum. The curriculum is well-structured, attractive for students and has a good balance between core courses, electives and projects. The PBL/RBL-approach is clearly visible in the courses and projects and very much valued by students. According to the panel, this approach is very well suited to the small-scale, interdisciplinary and international character of the programme, as it allows students from diverse backgrounds to contribute to interdisciplinary challenges and to learn from each

other. The panel considers the choice for English as language of instruction a natural choice for an academic master's programme. The international classroom in combination with PBL stimulates a global awareness in students that can be very helpful for their future career in an international environment. The panel did notice that the programme does not explicitly monitor the division of tasks in project groups. According to the panel, this could lead to 'specialization', where students practice skills that they are already good at rather than those that they still need to develop. It suggests that the programme consider incentives for students to change roles in project groups.

Based on the content of the core courses and discussions during the site visit, the panel recommends expanding attention to ethics in the curriculum. The current discussion of ethics mainly covers FAIR data principles, whereas the panel considers ethics to be broader than that, in particular in the case of handling medical data. According to the panel, the curriculum should at least cover basic ethical principles relating to bioethics and privacy and data protection (GDPR), as well as ethical procedures relating to experimentation and ethical committees. Furthermore, the panel recommends reflecting on whether all students obtain comparable knowledge in scientific programming as well as dynamic modelling. The panel considers these to be core skills for graduates in systems biology, but notes that they are mainly covered in electives. If necessary, the programme should expand the core courses to guarantee that all students are sufficiently trained in these skills. The panel noticed in the theses it read in preparation for the site visit that some students struggle with formulating sharp and realistic research questions and hypotheses as well as verifying these in otherwise very good theses (see Standard 4). It recommends evaluating the attention paid to this academic skill within the courses and projects and strengthening this wherever necessary.

During the site visit, the panel spoke with programme representatives about the pros and cons of a large thesis project versus two smaller projects, as several other programmes offer. Both students and teaching staff appreciate the large research project at the end of the programme. They feel that this gives students the chance to develop in-depth knowledge and skills in a particular topic. On the other hand, having students execute two research projects allows them to complete the research cycle twice, applying the lessons learnt in the first project to the second. Moreover, students could also experience two different research environments, for instance in academia and in industry. The panel suggests reflecting on this and determining whether the option to split the research project into two smaller projects is desirable in the light of the programme's aims.

Feasibility and student support

To promote the feasibility of the curriculum, the programme invests heavily in the admission and intake procedures. Its interdisciplinary character leads to a diverse intake that the programme aims to bring to a similar level within the first semester. Eligible for admission are students with a BSc in natural or exact sciences that have completed at least 15 EC of mathematics courses on a BSc level. Furthermore, students need to be motivated, have research experience or interest, and have sufficient command of English. To demonstrate this, students submit a letter of motivation and two letters of recommendation to the Board of Admission. The Board does not use quantitative criteria for selection, but rather looks at the complete picture of the skills and motivation of students. Before the start of the programme, students are assessed on their mathematical skills and are assigned to either the Mathematics of Biological Systems, or the Biology and Physiology course based on their assessment result and background. if necessary, students are provided with suggestions for additional study material to fill any knowledge gaps. Students from BSc programmes outside UM receive a two-day training programme on PBL to familiarize them with the didactical concept used in the programme. The panel was glad to see that the programme has a flexible attitude towards the 85% mandatory attendance of courses that is required to make PBL courses work: students can be exempt from this rule if personal circumstances interfere with this .

To further improve the feasibility of the programme, each student is paired with an academic advisor, one of the teaching staff members, who helps the student shape the curriculum to fit their ambitions and goals. The advisor helps students selecting electives and research topics, and regularly meets with the student to reflect on the achievement of these personal goals. Students are stimulated to stick to the curriculum schedule; there are two fixed moments in the year at which students can start their thesis trajectory, each with its own graduation moment. The resulting success rates are very high in comparison to those of other programmes in the Netherlands: approximately 85% of students complete the programme within two years.

The panel concludes from the documentation and interviews during the site visit that students feel very well supported throughout the programme. They are satisfied with the guidance they receive and particularly value the small-scale setting of the programme, which allows for close collaboration between students and teaching staff. The admission procedure helps them identify and remedy any knowledge gaps, and students feel well-equipped for the remainder of the programme. Students need to work hard to successfully complete their courses and projects, but feel that the programme is overall feasible and allows them to complete it within the designated time. The panel agrees with these observations and praises the attention the programme pays to feasibility and study guidance. It notes that this has translated into high student satisfaction as well as high success rates.

The panel noticed that the admission criteria for mathematics and biology are somewhat unbalanced. The programme uses specific criteria as well as an assessment to determine the mathematical skills of students, whereas the required biological skills are not made explicit. The panel recommends providing prospective students with more insight into what level of biology is advisable on entering the programme, possibly accompanied with recommended literature or courses for students that want to improve their knowledge on their own initiative.

The panel understood from the materials that the programme has low conversion rates: only 10-15% of students that apply to the programme ultimately enrol. The programme is investigating possible explanations and remedies for this issue with the help of the FSE and UM. Initial observations show that a high proportion of applications is not completed for unknown reasons, and applicants often do not reply to the programme's request for further contact. Additionally, some applicants withdraw from the process when they get admitted to other programmes for which they applied. The programme hopes that the new UM applicant portal, planned to go live in 2022-2023, as well as more targeted recruitment, will make the admission procedure more successful and less time-intensive for the programme. The panel wholeheartedly supports this.

The panel understood from the interviews that the programme is considering more flexibility with regard to the two fixed starting dates for the thesis. The panel supports this: it understood that this limitation is mainly motivated by administrative reasons. The panel considers more flexibility in this regard to be desirable for a master's programme, where students are largely responsible for their own planning.

Education during the COVID-19 pandemic

The lockdowns during the COVID-19 pandemic had a relatively small impact on the continuity of education within the programme. The PBL approach could be very well translated to an online setting with small-scale meetings. Due to the low student numbers, on-campus education could resume in small groups in most of 2020 and 2021. Facilities for hybrid education were provided throughout this period for students unable to attend in person. Most students were not dependent on labs for their research projects and master theses, and could proceed as planned. For the few students that were limited in their progress due to covid-related reasons, extensions to research projects or resits for exams were given on an individual basis by the Board of

Examiners. During the lockdowns, the programme stayed in close contact with its students through extra online meetings where all affairs concerning education, personal progress and well-being could be discussed. The panel praises the programme for its efforts and noticed that students, even though they very much welcomed a return to on-campus education, felt sufficiently supported during the pandemic.

Teaching staff

The programme is taught by a multidisciplinary teaching staff originating from either FSE or the collaborating faculties FHML and FPN. This staff teaches the core courses as well as the electives. The teaching staff members all hold a doctorate and are active researchers, most within the MaCSBio institute, and are as such involved in various research and R&D projects. For the data science-oriented courses, the programme involves teaching staff from the Department of Knowledge Engineering (DKE) within FSE. The UM trains and supports all teaching staff to work with the PBL principles: first through the mandatory University Teaching Qualification (UTQ) courses, and afterwards in the Continuing Professional Development (CPD) programme. All members of the core staff have completed the UTQ courses or are in the process of completing it. Regarding English-language proficiency, UM policy requires all non-native speakers in the teaching staff with more than 10% teaching appointment to have a minimum C1 proficiency. Exemptions can be given to staff that reach retirement age within less than three years. Staff members that do not meet this criterium are provided with training opportunities.

The self-evaluation documents and interviews during the site visit have given the panel a very positive view of the teaching staff. The staff is interdisciplinary and covers all essential expertise. Students describe their teachers as having tremendous experience, providing good guidance and being very approachable and accessible. The panel subscribes to this view. The programme is organized by an enthusiastic, motivated and relatively young core team of researchers, supplemented with several experienced full professors who contribute to the courses. The small size of the student cohorts results in an interactive research setting where students can work closely with their teachers. Staff members indicated during the interviews that they do not only teach students, but sometimes learn from their contributions to the courses and research projects as well. The programme management invests in coherence of the team, for instance through meetings where staff members can exchange knowledge and experience. Professionalization of the staff is high on the agenda through the UTQ and CPD programmes. The panel understood that all new teaching staff follow the UTQ courses, including PhD students that contribute to the teaching and are interested in developing their teaching skills. The panel also applauds the strong programme management for actively working on continuous development of the programme, based on solid educational principles.

Programme-specific facilities

The programme uses the lab facilities of the three participating faculties for project work and practical skills training. This includes for instance biomedical experimentation and molecular imaging. Students have their own place in the main building on the Randwyck campus. Due to the online nature of the site visit, the panel could not visit the facilities, but it concludes based on the documentation and the students' appreciation that the facilities are up to standard.

Considerations

The master's programme Systems Biology has translated its intended learning outcomes into a well-structured and attractive curriculum. The Problem-Based Learning approach is clearly visible and well-suited to the small-scale and diverse character of the programme. The curriculum is well-balanced with regard to core courses, electives and projects. According to the panel, the core curriculum could be further improved by expanding attention to ethics, in particular with regard to handling medical data and ethical procedures for experimentation. The programme should also evaluate whether all students are sufficiently trained in

scientific programming, dynamic modelling and the verification of hypotheses in research, and adapt the curriculum accordingly. The choice to offer the programme in English is well-supported and fits the international character of the field.

Students are very well supported throughout the programme, including during the COVID-19 pandemic. The admission procedure and the start of the programme helps students identifying and remedying any knowledge gaps, and students receive guidance to help them tailor the curriculum to their preference. This has translated in high student satisfaction and high success rates. Regarding the admission criteria, the panel recommends providing prospective students with more insight into the advisable level of biology, so they can improve their knowledge if they desire to do so. Furthermore, the panel considers the two fixed starting dates for the thesis to be rather strict and supports the initiatives to offer more flexibility in this regard.

The programme is taught by an enthusiastic and motivated teaching staff with a diversity of expertise relevant to the programme. The small-scale setting allows for close collaboration between staff and students, which is very much appreciated by both sides. The programme management is dedicated to the continuous development of the programme and has knowledge exchange and professionalization high on the agenda.

Conclusion

The panel concludes that that the programme meets Standard 2.

Standard 3. Student assessment

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

Findings

Assessment system

The assessment system within the programme is based on the principle of constructive alignment. Teaching and assessment methods are designed to best achieve the programme's ILOs and to assess the standard at which they have been achieved. The programme uses multiple types of assessment per course to best assess the different course objectives. Assessment methods include written exams, presentations, reports, assignments, essays and peer assessment. Each course has a course assessment plan composed by the associated teachers, that is evaluated, adjusted and aligned with the plans of other courses in an annual cycle involving the programme director, the examiners and the Board of Examiners. In the case of group projects, students are always assessed on both the individual and team level, to prevent free-riding. During the COVID-19 pandemic, written exams were replaced with alternative assignments wherever possible, and in the few cases that this was undesirable, online exams were organized in close collaboration with the Board of Examiners. This period was relatively short, as the small scale of the programme quickly allowed for on-site exams again.

The programme shares a Board of Examiners with the MSc Biobased Materials, consisting of a teaching staff member of each of the programmes and two external members from other faculties. The Board aims to select external members with relevant disciplinary expertise, fitting the interdisciplinary character of the programme. The Board is involved in the quality assurance of assessment within the programme in various ways. It approves of the course assessment plans each year, following up on issues regarding assessment

from course surveys conducted by the Educational Programme Committee. It also performs a post-hoc check of a sample of exams and theses each year.

The panel is positive on the system of assessment in the programme. The assessment methods are varied and fit the learning goals of the individual courses as well as the overall ILOs. Students are satisfied with assessment within the programme, both in the regular curriculum and during the online assessments in 2020. The programme pays sufficient attention to the individual attainment of the ILOs in group projects. It has solid quality assessment procedures in place regarding assessment. Based on the documentation and the interview during the site visit, the panel concludes that the Board of Examiners functions well. It is well-informed on assessment within the programme and has a proactive role in safeguarding the quality of assessment. The mix of internal and external members allows the Board members to learn from each other and use the best practices from multiple programmes.

During the site visit, the panel discussed the assessment of programming code with programme representatives. While programming as a skill is an element in many courses, code quality as such is not assessed in any of the courses or projects. According to the panel, the academic and professional fields are increasingly realizing the importance of code that is not only functional, but also well-designed and maintainable. It challenges the programme to incorporate this element into its assessment. The programme could for instance add quality of code to the rubric of relevant projects, including the master's thesis.

Thesis assessment
Students complete the programme with an individual thesis. Assessment of this thesis consists of five elements: proposal (5 EC), mid-term evaluation (6 EC), written thesis (15 EC), final evaluation (12 EC), and presentation and defence (10 EC). Each element needs to be completed with a satisfactory score. All elements are assessed by the research supervisor of the student, who is often the daily supervisor of the student during the execution of the thesis. In the case of an external daily supervisor, when a student performs his or her research project at another university or company, the role of first supervisor is taken on by an internal UM-examiner. The external supervisor then provides the examiner with input regarding the execution of the project and the performance of the student in the daily research practice for the mid-term and final evaluation. A second assessor, who is an expert not involved in the thesis process, provides a second opinion on the research proposal and independently grades the written thesis, presentation, and defence. The resulting grade is the average of the two assessments (written thesis), or results from consensus between the two assessors (presentation and defence). The student is provided with feedback on the thesis assessment form, as well as through annotations in the written thesis.

The panel considers these assessment procedures to be well-designed. The use of an independent second examiner is a good quality assurance measure, and the division of assessment into five elements helps students keep on track with their thesis and gives them multiple opportunities to demonstrate their skills. The panel noticed with appreciation that the programme adapted its thesis assessment procedure to always include two internal UM examiners for external theses based on the recommendations of the previous accreditation panel.

As part of its preparation of the site visit, the panel studied 15 theses with the accompanying assessment forms. It concludes that the form has useful subcriteria and rubrics to evaluate the thesis. Particularly the new form currently in use provides a very insightful and transparent substantiation of the grades given. The examiners provide ample feedback to the students. The panel especially values the annotated version of the thesis that students receive, which contained valuable feedback for students.

The panel noticed that the thesis grades given in the programme are very high, with 64% of the students receiving an 8.5 or higher in 2019-2020. The panel agreed that the theses are generally very good (see standard 4), but would have given somewhat lower (0.5 or incidentally 1.0) grades in several cases. It learnt that the Board of Examiners came to the same conclusion, and advised to adapt the rubric, which it felt encouraged giving high grades. This was implemented per 2021-2022 and is expected to lower the average thesis grades. The panel agrees with this analysis. It recommends investigating whether the measures have the desired result.

Considerations

The programme has a valid, transparent and reliable system of assessment in place. The assessment methods are varied and fit the goals of the programme. Assessment in the programme is supported by solid quality assessment procedures and a well-functioning and proactive Board of Examiners. The programme successfully changed to online examination during the relatively short time this was required in the COVID-19 pandemic. To further improve the assessment system, the panel suggests adding assessment of code quality to the curriculum. Thesis assessment is well-designed, with an insightful and transparent assessment form and much attention to feedback. The grading is transparent and valid, but has a tendency to drift towards the high end of the spectrum. The panel supports the adjustments to the rubric aimed at recalibrating this.

Conclusion

The panel concludes that that the programme meets Standard 3.

Standard 4. Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.

Findings

Thesis quality

Prior to the site visit, the panel studied 15 theses of the programme. The panel concludes that the theses are generally of high or very high quality. They are well-structured and cover interesting and relevant topics in systems biology. Some students seemed to struggle with the definition and verification of hypotheses: the panel recommends investigating whether this research skill should be strengthened in the curriculum (see Standard 2). According to the panel, the theses demonstrate that all students convincingly achieve the intended learning outcomes. Although it felt the grades were slightly inflated (see Standard 3), it concludes that the programme delivers very good graduates. It learnt during the site visit that theses regularly lead to (contributions to) publications after graduation, which it considers to be additional proof of the quality of the graduates. The panel thinks this is partly caused by the inherent attractiveness of the field of systems biology to very good and highly motivated students, and partly by the high-quality small-scale education that students receive in the programme. It praises the programme for this achievement.

Alumni

The programme is relatively young and has delivered 35 graduates so far. First indications of careers pursued after graduation show that approximately one-third of the graduates obtain a PhD position, and the other two-third end up in various positions in research and industry. The panel learnt from the programme management and students that graduates of the programme are in high demand in industry and academia, and usually quickly find a job after graduation.

Considerations

The panel concludes that graduates of the programme achieve the intended learning outcomes. The theses are generally of very high quality, for which the panel praises the programme. Alumni find relevant positions after graduation and are in high demand.

Conclusion

The panel concludes that that the programme meets Standard 4.

General conclusion

The panel's assessment of the MSc Systems Biology is positive.

Development points

1. Work on the visibility and reputation of the programme, for instance by making the biomedical profile more explicit as a strong point, and by making non-academic career options more prominent in the profile and aims of the programme.

2. Update the ILOs to reflect the high level that students achieve in for instance creation and evaluation skills and formulating the level that all students should achieve in the various disciplines that contribute to the interdisciplinary field of systems biology.

3. Expand attention to ethics in the curriculum to include basic ethical principles relating to bioethics, privacy and data protection (GDPR), as well as ethical procedures relating to experimentation and ethical committees.

4. Provide prospective students with more insight into what level of biology is advisable on entering the programme, possibly accompanied with recommended literature or courses for students that want to improve their knowledge on their own initiative.

5. Incorporate assessment of programming code quality to the programme.

Appendix 1. Intended learning outcomes

A graduate of the MSc System Biology programme has achieved the Programme Final Qualifications listed below:

Dublin descriptor	Intended learning outcomes (ILOs)
1. Students have a breadth of academic knowledge	**1.1 CORE KNOWLEDGE** Students have profound knowledge and understanding of the field of systems biology, in particular the combination of the underlying scientific fields of Biology and Mathematics as well as computational and experimental aspects of systems biology.
	1.2 SYSTEMS BIOLOGY FIELD KNOWLEDGE Students are able to identify appropriate theoretical frameworks to address a systems biology problem. Students can connect concepts across disciplines and integrate and apply models, theories, methods and techniques in the field of systems biology and have thorough knowledge of a specialty within the study programme, or thorough knowledge on the interface of the study programme with other fields.
	1.3 DISCIPLINE KNOWLEDGE (Biology) Students have gathered detailed knowledge and understanding of foundations of normal and pathological biological systems.
	1.4 ACADEMIC KNOWLEDGE Students are able to comprehend new emerging concepts, theories and techniques and use these to initiate creative research for solving relevant problems in the field of systems biology.
	1.5 DISCIPLINE KNOWLEDGE (Maths) Students have gathered detailed knowledge and understanding of analysis of biological datasets and modeling of biological systems.
	1.6 TOOLS KNOWLEDGE Students have detailed knowledge and understanding of tools for modeling and analysing biological systems.
2. Students can apply their knowledge and understanding, and problem-solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study	**2.1 PROBLEM-SOLVING** Students have the academic skill to independently identify, formulate, analyse and suggest possible solutions to problems in the field of systems biology.
	2.2 CONDUCTING RESEARCH Students have the academic skills to independently propose and conduct research on a problem concerning systems biology, including its experimental design, data collection and management, analysis, modeling and model validation, and report on it in a manner that meets the customary standards of the discipline. Students have the ability to perform original and innovative scientific and translational research in systems biology.
	2.3 CONTRIBUTIONS Students possess professional and academic skills to provide substantial and potentially leading contributions in a multidisciplinary team, crossing the boundaries between disciplines within systems biology.
	2.4 CONTEXTUAL AWARENESS Students understand the context of systems biology within science and society and are capable of applying the knowledge and understanding gained in the discipline of systems biology in a broader social context.
	2.5 PROFESSIONAL ATTITUDE Students have the ability to apply knowledge and understanding to complex, multi- or interdisciplinary problems, to formulate solutions and sustain arguments for those solutions in a professional fashion, both independently and in a team. Students are capable of applying knowledge and understanding in a way which demonstrates a professional attitude and ethical responsibility to their work or profession.
	2.6 APPLICATION OF TOOLS Students can describe and explain biological systems through applying mathematical and computational methods.
	2.7 DATA-BASED INSIGHT Students can analyse biological datasets through mathematical and computational approaches to suggest new hypotheses and functional experiments.
3. Students have the ability to integrate knowledge and handle complexity, and formulate judgments with incomplete or limited information, but that	**3.1 SCIENTIFIC ATTITUDE** Students have a scientific attitude aimed at learning and generating new knowledge and viewpoints.
	3.2 CRITICAL ANALYSIS Students are capable of evaluation of research results obtained and derivation of new scientific insights. Students are able to find and critically analyse relevant scientific publications or research proposals including hypothesis, problem definition and approach, interpretation of results, conclusions and limitations.

include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgments;	**3.3 SOCIAL RESPONSIBILITY** Students are able to discuss and predict the impact, effects and application of systems biology on human society and the environment they live in.
	3.4 ETHICS Students have developed into responsible and ethical scientists are aware of the relevance and applications of systems biology.
4. Students can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously;	**4.1 COMMUNICATION AND TEAMWORK** Students are capable of communicating in English their conclusions, as well as the underlying knowledge, grounds and considerations, to an audience composed of specialists or non-specialists. Students can communicate and create links with and between scientists and experts. Students have the ability to communicate and cooperate in multidisciplinary teams with focused assignments and collaborate effectively and appropriately with people from different socio-cultural and national backgrounds.
	4.2 EVALUATION Students have the capability to perform and communicate self- and peer-evaluation in order to continually improve themselves and their peers
5. Students have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous	**5.1 INNOVATIVE ATTITUDE** Students demonstrate a creative and innovative attitude in their work that is driven by life-long learning.
	5.2 CRITICAL THINKING Students have the ability to reach and support a conclusion in a logically structured fashion based on evidence, in an intellectually honest and reflective fashion. They are able to comprehend new emerging concepts, theories and techniques and use these to initiate creative research for solving relevant problems in the field of systems biology.
	5.3 LEARNING Students are able to optimally extract information provided / resulting from lectures, group assignments, journal clubs etc. Students are able to effectively use Problem-Based Learning.
	5.4 EXTEND KNOWLEDGE Students have the ability to independently maintain and extend professional knowledge and competences.

Appendix 2. Programme curriculum

Table 1 General curriculum

	8 weeks	8 weeks	4 weeks	8-9 weeks*	8-9 weeks*	4 weeks
Year 1	Compulsory Courses	Compulsory courses	Project	Elective courses	Elective courses	Project
Year 2	Elective Courses	Master Thesis research project				

**Adjusted to compensate for various public holidays.*

Table 2 Curriculum structure 2020-2021

Year 1	**Period 1**	MSB1001 Systems Biology (6 ECTS)
		MSB1002 Biology and Physiology * (6 ECTS)
		MSB1003 Mathematics of Biological Systems * (6 ECTS)
	Period 2	MSB10014 Modeling Biosystems (6 ECTS)
		MSB1005 Experimental Design & Data Management (6 ECTS)
	Period 3	Research Project 1 (6 ECTS)
	Period 4	*2 of the following 3 electives:*
		MSB1006 Omics (6 ECTS)
		MSB1007 Cardiovascular Systems Biology (6 ECTS)
		MSB1008 Dynamical Systems & Non-Linear Dynamics (6 ECTS)
	Period 5	*2 of the following 3 electives:*
		MSB1009 Fundamental & Systems Neuroscience (6 ECTS)
		MSB1010 Modeling Metabolism (6 ECTS)
		MSB1011 Machine Learning & Multivariate Statistics (6 ECTS)
	Period 6	Research Project 2 (6 ECTS)
Year 2	**Period 7**	*2 of the following 4 electives:*
		MSB1013 Computational Neuroscience (6 ECTS)
		MSB1014 Network Biology (6 ECTS)
		MSB1015 Scientific Programming (6 ECTS)
		MSb1017 Commercialization and Entrepreneurship (6 ECTS)
	Period 8-12	Master Thesis Research MSB (48 ECTS)

* Students are assigned to one these courses based on the focus of previous academic study.

Appendix 3. Programme of the site visit

1 DEC 2021		
15.00	17.00	Preparatory panel meeting
17.00	17.30	Consultation hour
2 DEC 2021		
08.30	09.00	Arrival and preparation
09.00	09.45	**Interview programme management**
10.00	10.45	**Interview EPC**
11.00	11.45	**Interview students/alumni**
11.45	12.30	Lunch break
12.30	13.15	**Interview teachers**
13.30	14.15	**Interview Board of examiners**
14.30	15.00	Internal panel session
14.30	15.00	**Concluding interview programme and faculty management**
15.00	17.30	Panel deliberation
17.30	18.00	Oral feedback and conclusion

Appendix 4. Materials

Prior to the site visit, the panel studied 15 theses. Information on the theses is available from Academion upon request. The panel also studied other materials, which included:

- Overview staff members
- Education and Examination Regulations (EER)
- Addendum EER
- Rules and Regulations
- Informational videos programme, Faculty and MaCSBio
- Assessment Policy
- Assessment Programme
- Assessment Plan (format)
- Course Coordinator Handbook
- Plan for hybrid education
- Plan for transition to on-site education
- Examples of Course Manuals
- Constructive alignment curriculum
- Master Thesis Information