The Research Council of Norway

Evaluation of Mathematics, ICT and Technology 2023-2024

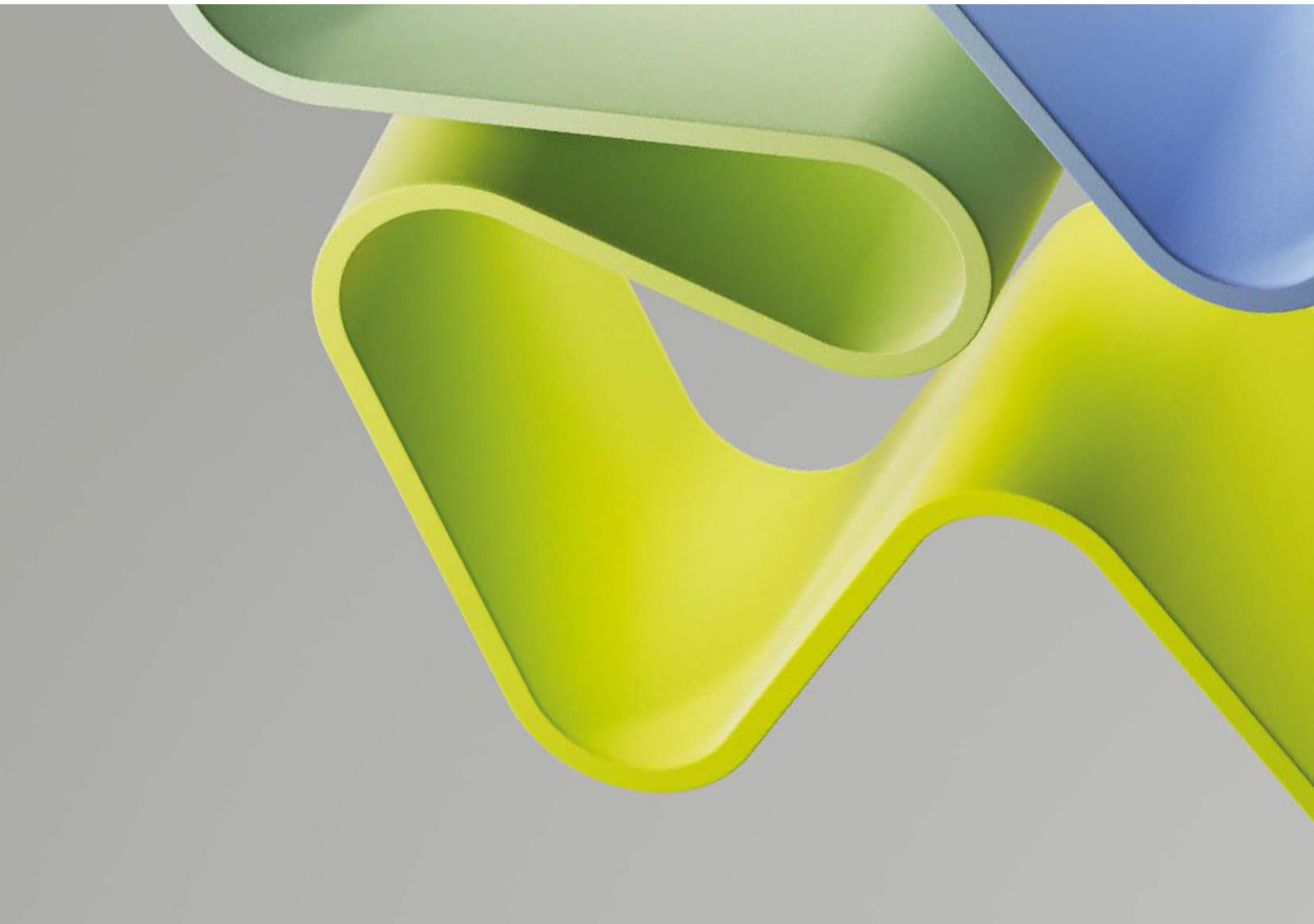
Evaluation Report for Administrative Unit

Administrative Unit: **Department of Mathematical Sciences (IMF)**

Institution: **Norwegian University of Science and Technology (NTNU)**

Evaluation Committee Higher Education Institutions 1

December 2024



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Statement from Evaluation Committee Higher Education Institutions 1

The members of this Evaluation Committee have evaluated the following administrative units at the higher education institutions within Mathematics, ICT and Technology 2023-2024 and has submitted a report for each administrative units:

- Department of Informatics, University of Bergen (UiB)
- Department of Mathematics, University of Bergen (UiB)
- Department of Informatics, University of Oslo (UiO)
- Department of Mathematics, University of Oslo (UiO)
- Department of Computer Science (IFI), UiT The Arctic University of Norway
- Department for Mathematics and Statistics (IMS), UiT The Arctic University of Norway
- Department of Mathematical Sciences (IMF), Norwegian University of Science and Technology (NTNU)
- Department of Computer Science (IDI), Norwegian University of Science and Technology (NTNU)
- Department of Mathematics and Physics (IMF), University of Stavanger (UiS)
- Faculty of Engineering and Science (TekReal), University of Agder (UiA)
- Department of Electrical Engineering and Computer Science (IDE), University of Stavanger (UiS)

The conclusions and recommendations in this report are based on information from the administrative units (self-assessment), digital meetings with representatives from the administrative units, bibliometric analysis and personnel statistics from the Nordic Institute for Studies of Innovation, Research, and Education (NIFU) and Statistics Norway (SSB), and selected data from the National survey for academic staff in Norwegian higher education and the National student survey (NOKUT). The digital interviews took place in the autumn 2024.

The members of the Evaluation Committee are in collective agreement with the assessments, conclusions and recommendations presented in this report. None of the committee members has declared any conflict of interest.

The Evaluation Committee consisted of the following members:

Professor Rebecka Jörnsten (Chair),

Univ. Gothenborg/Chalmers

Professor Matthias Schütt,
Leibniz Universität Hannover

Professor Jan Hesthaven,
École Polytechnique Fédérale de Lausanne

Professor Mads Nielsen,
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Professor Tiziana Margaria,
University of Limerick

Dr. Joanna Staneva,
Helmholtz Zentrum Hereon

Professor Björn Engquist,
University of Texas at Austin

Professor Plamen Angelov,
Lancaster University

Description of the Administrative Unit

The research activity is divided into five main groups, each with its own leader, along with smaller groups focusing on mathematics education and basic engineering education. The department has focused on hiring young talent, particularly women, by offering associate professor positions, improving gender balance among new hires. There are currently 25 associate professors, 21 postdocs, and 85 PhD candidates, with the proportion of female PhD candidates at around 20%, which remains a challenge.

Research is managed by the groups and individual researchers, with oversight from the Head of department, and supported by the Deputy Head for research. The unit is involved in both a Centre of Excellence and a Centre for research-based innovation, collaborating with other faculties. The Deputy Head oversees the PhD programme in Mathematical Sciences, ensuring the quality of research training, and supports funding applications. The unit contributes to strategic areas of data science, digital twins, and mathematics in technology at the faculty level.

The research is organised in the following research groups:

- Analysis
- Geometry and Topology
- Algebra
- Differential Equations and Numerical analysis (DNA)
- Statistics

The department employs mathematical and statistical methods to enhance the understanding and testing of new digital tools, focusing on areas like cryptography, signal processing, and the integration of statistical methods with deep learning and neuroscience. These efforts align with the faculty strategy (2018-2025) to promote a smart, safe, and sustainable future, while also contributing to the university's strategic areas of Health, Oceans, Energy, and Sustainability. As the largest mathematical sciences department in Norway, it oversees all mathematics and statistics service teaching, emphasizing high-level teaching skills in recruitment. The unit supports researchers in securing prestigious funding by offering teaching relief and prioritizing younger researchers with reduced administrative burdens. Future hiring plans aim to maintain a balance between theoretical and applied research, while also fostering a positive work environment.

The unit actively fosters national and international research networks and seeks external funding to support these networking activities. Research projects funded by the Research Council of Norway (RCN) include components for international collaboration, providing mobility funds for guest professors and travel funds for conference participation and research visits. PhD students with RCN grants can also access additional mobility funding for longer research stays abroad. This approach enhances the mobility of younger researchers and strengthens the unit’s contributions to its sector.

Overall Assessment

The administrative unit, NTNU-IMF, is the largest department of mathematics and statistics in Norway and has the largest production of PhD students. The administrative unit should also be commended for its high level of research output in the form of publications and externally supported research projects and for being a central part of the outstanding Norwegian University of Science and Technology. The educational program across all different level is substantial and highly appreciated within NTNU. There is extensive collaborative research interaction with the external national and international academic community, government agencies, research institutes and industry.

NYNU-IMF is divided into five research groups, Algebra, Analysis, Geometry and topology, Differential Equations and Numerical Analysis, and Statistics. The different groups have substantial independence and together they cover most parts of modern mathematics and statistics. The Algebra group houses Cryptography, which is less common. Overall, the administrative unit is active with successful applied and theoretical research. All groups have a high level of publication in good journals and an impressive number of PhD students. In the separate evaluations of the groups, they all came out extremely well with no group underperforming.

The gender balance in the administrative unit is on par or better than comparable international universities on all levels except for PhD students. More efforts is needed to attract a larger fraction of female students.

There are other challenges for the unit, which must be tackled. One is the expected downturn in government funding in the coming years due to budgetary constraints and the expected reduced number of incoming students. External funding for research projects and student support is lower than desired. One reason is that the funding agencies nationally and internationally are gradually turning towards larger but fewer grants. This is a challenge for mathematics in general and for pure mathematics in particular but could partially be met by increasing collaborative efforts. Research projects with industry and institutes are useful for funding but also as a source of inspiration for research and for support to society in general. This activity could be increased.

The lack of major recognitions, for example, ERC grants is another problem. NTNU-IMF has never had any ERC grants while at least one smaller mathematics department has currently three ERC grants. ERC grants do not solve all problems and getting them includes a component of luck. Major prestigious awards are nevertheless very important for recognition, which further has implications for the prestige of the unit within NTNU and across Norwegian academia, for funding from other sources and for attracting and retaining exceptional faculty and students. The compressed salary structure compared with some other countries has benefits but may also create obstacles for retention of talents when attemptinh to match outside offers.

The Terms of Reference for the administrative unit is attached to the report.

Recommendations

To address some of the identified weaknesses and future challenges of the administrative unit, Department of Mathematical Sciences, the following recommendations should be considered.

1. Develop a clear vision for the future of the NTNU-IMF, resulting in a plan for research focus, hiring, course and personnel development and for meeting the financial challenges.
2. To achieve an even higher level of excellence, searches for new faculty could be broad. Simply replacing retired professors with someone in the same field may not work well in a changing environment, scientifically and financially.
3. The unit should also consider hiring exceptionally promising junior faculty and mentor them for success. Tenure-track positions is one possibility.
4. Younger faculty members would benefit from lower teaching load and increased mentoring.
5. Increase the efforts for achieving a more gender balanced graduate student body.
6. Increase collaboration with other units inside and outside of Norway. This should not be restricted collaborative research but also for funding opportunities. ERC Synergy grants can be a target. Collaboration with centers at NTNU, SINTEF and local industry is already good and, if possible, should be extended.
7. There are advantages of the independence of the different research groups, but this should not hinder improved research and teaching collaborations between the groups.
8. If the financial challenge becomes serious, different strategies should be considered. Examples are introducing career teaching positions and having postdocs taking up a larger fraction of teaching than is currently the case.

There are other issues to be considered if the Department finds them relevant.

9. It is not so common today internationally with having Didactics faculty in mathematics departments. It might be possible to achieve the very important didactics goals in other ways than hiring new faculty when the current faculty retires.
10. Develop a policy to handle AI. It begins to penetrates all aspects of society and is of high interest of the students. The field is however rapidly developing and requires large resources. It is therefore important that any research and educational efforts in this direction are focused and fits the Department strategy.

1. Strategy, resources, and Organization of Research

1.1 Research Strategy

NTNU-IMF, as most universities, aims at conducting high-quality research across both theoretical mathematics and applied research including curiosity-driven and interdisciplinary research. The strategy is to have strong research in all major fields represented in the research groups, Algebra, Cryptography, Analysis, Topology, Geometry,

Differential Equations, Numerical Analysis, Optimization and Statistics. A specialty is the successful activity in cryptography. To encourage research, there is a dynamic allocation of teaching duties, which allows certain faculty to focus more on research. There is also support for major grant applications. NTNU-IMF is promoting a good working environment and was awarded the Work environment – employee award, 2022.

<u>Recommendations</u>

- Collaboration between the different research groups should be encouraged. One way is to consider hiring in fields connecting the current groups. Examples could be probability coupling analysis and statistics and differential geometry connecting geometry and partial differential equations.
- To increase visibility, faculty should be encouraged to publish in the very best journals and the, to be expected, lower acceptance rate should not be a handicap in promotions.

1.2 Organization of Research

The responsibility for pursuing research at the forefront of mathematics, to maximize the quality of the research output, and to build an appropriate scientific network is delegated to the research groups and to the individual researchers. Each of the five groups has a group leader. The Deputy Head for research helps the Head of department in matters of research. The leadership has regular exchanges of information with the research group leaders at the meetings of the advisory committee of the Head of department. This is a distributed structure that allows for initiatives from the individual groups and has served the Department well but induces the risk of making a shift of resources between groups harder. PhD training is the responsibility of the Research Committee at NTNU-IMF (composed of three professors, two PhD students and administrative support). Members of the Research Committee monitor the progress of the PhD candidates towards PhD completion.

Recommendations

- NTNU-IMF could consider establishing a common vision for the department which would help in research interaction between the groups and in the hiring process. There should be contingency plans for different financial scenarios.

1.3 Research funding

The Ministry of Education and Research is the major source of funding for NTNU-IMF with 69 MNOK/year. This is primarily driven by teaching and there is a risk of it being reduced in the years to come due to an expected reduced number of students. This is a serious challenge for the Department. RCN is a large contributor in form of research grants with 23 MNOK/year. The support from industry and from international sources is much more limited. The large fraction of funding connected to teaching means that teaching excellence is important, and this can be seen in the graduation numbers at all levels.

Recommendations

- All faculty should be encouraged to seek outside funding and to be rewarded for success. ERC funding will not contribute directly but makes it easier for the Department to attract other funding and collaboration.

1.4 Research Infrastructure

Research at NTNU-IMF is supported by administrative staff at the Department and at the NTNU-wide level. The different research centers at NTNU provide further infrastructure for projects associated with them. On the national level the Centre for Advanced Study and Sophus Lie Conference Center have been used by researchers at the Department. IT infrastructure exists on different levels, from local networks, storage and clusters to national High-Performance Computing and large-scale storage recourses. PhD students are asked to describe their data management plan in their PhD project description. All data sets, simulations, code and workflows associated with PhD theses are documented and made available online in accordance with the FAIR and CARE principles for Open Science.

Members of NTNU-IMF take advantage of several international infrastructure resourses, both as participants and organizers. Examples are Mathematisches Forschungsinstitut Oberwolfach, Germany, Institut Mittag-Leffler, Sweden and Isaac Newton Institute of Mathematical Sciences, UK.

Recommendations

- The unit could further encourage, administratively support and mentor faculty to apply for organizing programs at national and international centers as well as collaborative grants.

1.5 National and International Collaboration

The research groups at NTNU-IMF are active in an impressive number of national and international collaborations. The collaborative partners range from academic institutions and research institutes to industry. Support from RCN and NTNU-IMF facilitates several collaborative projects. Naturally many of them are applied but there is also substantial collaboration in pure mathematics. Some collaboration in applied areas is facilitated by the Centre for Biodiversity Dynamics, the Centre for Geophysical Forecasting and the Centre for Environment-friendly Energy Research. The partners include, for example, the Norwegian Institute for Nature Research and SINTEF. Several projects contain environmental components. The project CONWIND on control technologies for offshore wind farms is an example. On the pure side support from Trond Mohn Foundation is helpful and NTNU-IMF has been active in research programs at the Institute Mittag-Leffler in Stockholm.

Recommendations

- Increased participation in EU and ERC projects would improve the visibility of the Department and could be a factor in attracting faculty and students

1.5 Research Staff

NTNU-IMF is a large department with 38 professors, 25 associate professors. The balance between these two groups is normal for a leading research university. Some of the professors are approaching retirement. Hiring is focused on the associate professor level and the advancement to full professor is common. Currently there are no tenure-track professors. There were tenure-track associate professors hired during 2017-2020. There are 5 adjunct professors, 6 adjunct associate professors and 2 researchers, which are permanent positions. The number of postdocs is 21 and PhD students 85, which is impressive. The gender balance is overall at or above an international level for mathematics. The number of females among the PhD students is, however, low. Some of the associate professors have reduced research time due to a higher teaching load. This is particularly true for the employees at campus Gjøvik.

Recommendations

- The Department should seriously consider broader advertising, including on the professor level and tenure-track. This will allow the possibility of attracting established leaders and promising younger stars. The important balance between fields, age and gender should be considered over time. This also widens the chance of ERC starting grants.
- Extra effort to encourage female PhD applicants would naturally be important to achieve a more diverse student body.

- Younger faculty should be mentored in their career and preferably should have a reduced teaching load, at least not an increased load.

1.6 Open Science

NTNU has a well-developed open science policy, and this is followed by NTNU-IMF. It naturally involves open sharing and wide distribution of research outputs. All PhD students

are briefed on practices of Open Science at NTNU at the compulsory “PhD introduction”. There are also specific efforts in mathematics as, for example, the hosting of a new diamond open access international journal on representation theory,” Annals of Representation Theory”, aiming at publishing top quality original research articles in the general area of contemporary representation theory. All publications at NTNU-IMF are published as green open-access publications at the repositories, https://arxiv.org and NTNUopen. A large proportion of the scientific software developed at the Department is open source. There are, of course the natural restrictions for sensitive data.

NTNU-IMF is doing more than its fair share of following, developing and promoting robust open science policies.

2. Research production, quality and integrity

The research activity at NTMU-IMF is organized in five research groups. The pure part of the administrative unit is represented by the groups in Algebra, Analysis and Geometry and Topology. The applied mathematics is represented by the groups in Differential Equations and Numerical Analysis and Statistics. All are ranked very highly.

The Algebra group houses cryptograph, which has a very strong and active outreach program with many applications. The central field of representation theory is prominent in the group and highly successful. Analysis is a classical field, which is vey active at NTNU-IMF with an impressive publication record. It also contains an applied component with emerging research in machine learning. The group in Geometry and Topology is young and very successful. It has been active in different educational programs.

The research group in Differential Equations and Numerical Analysis is large and very productive in terms of publications and number of graduating students. The core field of research is the numerical solution of differential equations, and the group is internationally recognized for major contribution in this area throughout the years. The Statistics Group is also very strong and often focused on applied problems. Significant contribution has been done in outside collaboration.

Research integrity is taken seriously at NTNU. Regularly workshops are organized about research ethics and research integrity for leadership and employees. NTNU has established The Research Ethics Committee to address particularly difficult and uncertain cases. As part of the transferable skills training, a course on research ethics and research integrity is mandatory for all PhD students. The administrative unit for mathematical sciences is an integral part in all these efforts.

2.1 Research quality and integrity

The overall research production from groups measured in terms of published papers is impressive. With a 28.2% share of all publications from Norwegian universities and institutes with respect to modified author shares confirms its dominance. Many of these publications are in the best international journals and a sizable fraction of those in applied journals. Researchers from NTNU-IMF are often invited to give presentations at major international conferences and some have also received significant prizes.

Research group Algebra overall assessment

Strengths: The group is at the forefront of new scientific developments, like tau-tilting theory or the connection between topological data analysis and representation theory. The research in cryptography has produced advanced cryptographic functionalities like electronic voting

and interdisciplinary collaborations with people in computer science, making an outstanding contribution to society and the advancement of knowledge. The group's international visibility and extensive network make it possible to recruit excellent postdoc candidates, and associate professors. It has several strong master's students who will make excellent PhD candidates if sufficient PhD fellowships are available. The group has been very successful in acquiring competitive external funding for its research.

Weaknesses: Even though the group has been successful in attracting external funds, it has not obtained funds from EU projects, and it should spend more effort on these. The group has excellent publications and should try top general audience journals in mathematics to reach an outstanding position in the field. Cryptography is a crucial field of the research group, and it should have more than one permanent member working on it. The group's publications, along with their externally funded projects and conference organization involvement, further demonstrate the group's international standing and contributions to its research fields. All in all, the performances of the group are excellent, also compared to the international framework.

Research group Analysis overall assessment

Strengths: The Analysis group has members from various backgrounds who can offer diverse perspectives and approaches to solving problems in their respective areas. They have also a good mix of experienced and early-career mathematicians, fostering an environment where their students and postdocs can benefit from mentorship and supervision and publish in top journals both in general mathematics and within their field. The research results have received quite some attention in terms of prizes and membership in scientific academies for some of its members. A strong research production (more than 100 published journal articles between 2018 and 2022) and publications in top journals make the quality of the publications outstanding compared to the national and international environment. The group has an extended network of national and international relevant academic collaborators. Among the research interests of the group, is a new field of machine learning. This subject has exponentially increased its applications and raised a huge interest all over the world. This research area is very promising and makes the group very attractive on a national and international level.

Weaknesses: The group has got quite a few funds from the RCN. Anyway, despite its efforts, it has not been able to get as much funding as desired (the number is low compared to the number of proposals submitted). Several strong members have applied for European Research Council (ERC) grants in the different schemes and without success. But this failure is quite common also in strong international groups. Anyway, there is a discrepancy between the group's success in terms of publishing in top journals and research group contributions and the lack of recognition from the funding agencies. They have been very attractive for PhD and master students and should try to attract more bachelor students. Overall, the publication quality and the group's contribution to both theoretical and applied research are outstanding in an international context.

Research group Geometry and Topology overall assessment

Despite its young age, this is a very strong and determined group, also on the international level, which performs very well across all evaluation criteria. It has a clear adequate strategy which it is pursuing successfully – the only notable exception being the external (international) funding. Reaching its goals appears very likely. The contribution of the group to the educational and economic development of Norway and internationally is very considerable. The group is regularly engaged with high school students and is involved with

mathematics education in developing countries through the Centre International de Mathematiques Pures et Appliquées (CIMPA). In addition, there is a project with Tromskraft which has a relevant impact on the economic development, as it directly relates to renewable energy sources.

Strengths [mostly detailed above]:

• high quality research,
• high international visibility,
• great network of collaborators,
• excellent track record in mentoring and promoting young researchers,
• outstanding interdisciplinary projects,
• group largely increased (number of PhD students and postdocs going up from 4+1 to 12+3)

The main weaknesses are:

• limited success in acquiring external funding, in particular internationally; this may be partly a matter of bad luck, so it may be helped by time (and continued efforts)
• limited diversity and gender balance, despite the strategic efforts
• the outstanding interdisciplinary projects seem to rely on a single retired group member

Research group Differential Equations and Numerical analysis (DNA) overall assessment

The group maintains its goal of being internationally leading and, based on past history, it has the capacity to maintain this position. It performs well on all main parameters, including publication, mobility, talent training and attraction of external funding. It is highly competitive on an international scale. Its educational impact is likewise very substantial, having educated almost 180 master students and 44 PhD students during the last decade. These are very strong numbers for a core group of a faculty of 14, complemented currently by 20 PhD students. The visibility of the group is very high, due partly to the quality of research and education, but also due to the very active role the group has taken in organising conferences and workshops. The group has furthermore implemented a strong program for sabbatical leaves to encourage exchange and input of new ideas. It is furthermore highly collaborative, both within the group as well as participants in numerous external projects. One weakness is the engagement with society in which there is a strong emphasis on involvement in the mathematics community and in activities directly related to the research activities. A stronger role in outreach and engagement with the broader public should be expected. The gender balance with about 18% female members is reasonable but not exceptional. It is surprising to see that there are no women among the postdoctoral researchers. There is a real threat to the academic prominence posed by a substantial generational turnover – this will need to be addressed in discussions with the host institution and by opening for new directions of research and education aligned with the rapid developments in machine learning.

Research group Statistics overall assessment

The statistics group at NTNU is one of the strongest in Norway and is internationally competitive. They produce high quality research in mostly top outlets. The participate in interdisciplinary research at NTNU and through national and international collaborations and are involved in research with high societal impact (e.g. biodiversity, cancer, child mortality). The group’s focus is on academic research and scientific publication, but they also participate in outreach activities and conduct research with non-academic partners.

3. Diversity and equality

The diversity and equality efforts of the Department of Mathematical Sciences is fully integrated into the university wide initiatives at NTNU. This includes the plan for gender equality and diversity. NTNU-IMF aims to contribute to equality, tolerance, fulfilment of its social mission, and further development of NTNU as a diverse university. It is done in cooperation with the university leadership and HR group. The activities also include efforts to enhance the well-being of international employees and students, tackling of functional diversity, gender identity, discrimination and harassment. Most of this is best done university wide but there some areas where mathematics is different. The Department organizes every year a celebration of the Women in Mathematics Day, with research talks, videos and other cultural activities. The female professors and associate professors have been active participants in the forum for Women in Science organized by NTNU. The international students and staff play a very important role in the Department in all activities from research to enhancing its international viability. The overall gender balance is quite good and on par or better than comparable universities of technology. However, what sticks out at NTNU-IMF is that the fraction of females in the PhD program is lower than among faculty. This is unusual internationally.

A natural recommendation for improved gender balance at NTNU-IMF is thus to focus on students and young faculty. To encourage students and in particular females to apply to NTNU-IMF and an even more robust outreach program, aimed at high school students and undergraduates, would be helpful. Summer programs and other ways of inviting students to the Department could be increased. Undergraduates should be mentored and encouraged in different ways to join the graduate program. International students and new international faculty need extensive support in the early period after arriving and currently being in minority, females may need extra help.

4. Relevance to institutional and sectorial purposes

NTNU actively supports innovation and commercialization by its employees. There are guidelines, and organized legal support offered by NTNU. There is a Deputy Dean for

Innovation. Commercialization is dealt with together with NTNU Technology Transfer AS. Innovation and commercialization at NTNU-IMF are encouraged and typically done in large collaborative research and innovation projects together with external organizations. There are strong motivations for engaging in innovation and commercialization in terms of financial benefits, exposure to interesting research topics, as examples in teaching and support of industry and society in general. There are several examples of successful innovation and commercialization results, which, for example, can be seen in the list of impact cases in section 5, below.

NTMU-IMF has large master and PhD programs. There is a deliberate effort to have the students exposed to the research of the different groups. This is done via mentoring and group seminars where the PhD students are encouraged to give presentations. There is also an extensive number of advanced courses for the students to choose from. NTNU-IMF has also organized several summer/winter schools for young researchers with participation of national and international researchers both in the role of lecturers and attendees. These events were co-funded by externa sources and NTNU-IMF.

Recommendations

- Innovation and commercialization should be encouraged with benefit for the individuals involved, the university and society. This can be an inspiration in the mentoring process, but care must be taken with respect to IP, patent and licenses policies as well as potential conflict of interest and time conflicts.

5. Relevance to society

Mathematical research in general contribute directly or indirectly to progress in society, in particular, to science, technology and medicine. Researchers at NTMU-IMF collaborate directly with industry, government and research institutes resulting in research benefitting Norway and the international community. A good example, not common in other mathematics department, is the many contributions of the group in cryptography as is seen in the impact cases discussed below.

A major societal contribution is the educational program. NTNU-IMF contributes to society by educating bachelor's and master's students in mathematical sciences, students within the 5-years integrated master program in physics and mathematics, teachers in natural sciences and PhD students in mathematical sciences. All together, NTNU produces the largest part of the highly skilled experts in mathematical sciences for the Norwegian society. These mathematicians and statisticians find employment in industry, the public sector and academia. A good example of international cooperation is the Ethiopian Norwegian network in computational mathematics.

The impact cases presented by the Department of Mathematics are all highly relevant for society as discussed below. They are also diverse with respect to application areas and good examples how high-level original research at the Department often is anchored in relevant phenomena in the world outside of the university. They are, however, not so diverse with respect to the different groups in the department. All impact cases comes either from cryptography or statistics. With five cases presented it would have been natural to, for example, see at least one from the group, Differential Equations and Numerical Analysis.

5.1 Impact Cases

Comments on impact case 1, Smittestopp appen

The Google/Apple interaction tracking system used during parts of the COVID pandemic was designed with privacy in mind, but the (national) system for uploading tracking data after infection was suboptimal from a privacy point of view, potentially leaking infection status. This research developed cryptographic constructions and implemented them resulting in significantly improved the privacy of this part of the system. A cryptographic tool that can be used to solve this problem is anonymous single-use tokens. The underpinning research was to develop improved such schemes and increase their functionality to include metadata. The paper proposed a version zero knowledge proofs based on the traditional discrete logarithm problem in suitable cyclic groups, which does not have public verifiability. The main impact consists of increased confidence in the privacy of the contact tracing systems.

This is an excellent example of a timely research with a societal impact in a critical area at a critical time. It also has impact on the field of applied cryptography and has an educational component since the research was partially done by a graduate student.

Comments on impact case 2, Short observation series and geostatistical methods to improve Norwegian runoff maps

Water runoff is a key variable in hydrology and for the hydroelectric industry. Most areas in the world lack direct runoff measurements, and runoff then must be estimated. The mean annual runoff is typically based on 30 years of data. However, in many catchments there are shorter records. A new geostatistical model was developed that enabled short records to be used for estimating mean annual runoff to overcome this difficulty.

A valuable collaboration between the statistics group and hydrological scientist was established with focus on runoff modeling and uncertainty quantification.

Comments on impact case 3, Geophysical data inversion in a probabilistic setting

Geophysical reservoir characterization is critical for understanding properties of the subsurface. These case studies at the NTNU-IMF focus on petroleum companies' workflows and petroleum domain research resulting from research on Bayesian inversion at the statistics group. Norway is already in the forefront of reservoir characterization and modeling. This project develops and analyzes modern statistical tools in close collaboration with local industry. It sets new standards for probabilistic inversion based on seismic data.

This is an outstanding example of interaction with an important Norwegian industry. The impact is not only on the industry but also on the theory of probabilistic inversion and training of scientists.

Comments on impact case 4, Electronic voting, 2012-22

This case is about the design and analysis of cryptographic voting systems, and it was used as the basis for the cryptographic voting scheme in the 2013 trial of internet voting in Norway. The mathematical analysis increased confidence in the technical security of the voting system. This system was the foundation for the current voting system being developed and deployed in Switzerland, as well as the voting system currently being sold by Scytl. The key technical novelty in this class of schemes was a better method for computing so-called return codes, which are used by the voter to ensure that their ballot has been received correctly by the system, without compromising the privacy of the ballot. The Church of Norway elections in 2023 used this type of internet voting to simplify access to the election.

It is an outstanding achievement in this very visible area of cryptography and an important step in making voting online safely possible in the future. As in the other cases this was a team effort.

Comments on impact case 5, Modelling large-scale biodiversity data

Models for the distributions of species that can account for huge biases in the way the data were collected have been developed by NTNU-IMF. The models and related software have already been used to assess aspects of the current state of biodiversity in Norway and other countries, e.g. deer distributions in the UK and Ireland. A scientific challenge is that biodiversity data has biases. A lot of the data is collected in areas easily accessible to large numbers of people. Better designed surveys also tend to be much smaller. A way to combine the data to make use of the best of each data set and overcome the worst of each data set is at the core of this impact case. A side effect of this project is a new faculty member moving to NTNU.

This is a very good example of the research by the statistics group in coupling and developing modern methodology and applying it to essential societal phenomena.

Methods and limitations

Methods

The evaluation is based on documentary evidence and online interviews with the representatives of Administrative Unit.

The documentary inputs to the evaluation were:

- Evaluation Protocol that guided the process
- Terms of Reference
- Administrative Unit's self-assessment report
- Administrative Unit's impact cases
- Administrative Unit's research groups evaluation reports
- Bibliometric data
- Personnel and funding data
- Data from Norwegian student and teacher surveys (only for HEI's)

After the documentary review, the Committee held a meeting and discussed an initial assessment against the assessment criteria and defined questions for the interview with the Administrative Unit. The Committee shared the interview questions with the Administrative Unit at least two weeks before the interview.

Following the documentary review, the Committee interviewed the Administrative Unit in an hour-long virtual meeting to fact-check the Committee's understanding and refine perceptions. The Administrative Unit presented answers to the Committee's questions and addressed other follow-up questions.

After the online interview, the Committee attended the final meeting to review the initial assessment in light of the interview and make any final adjustments.

A one-page summary of the Administrative Unit was developed based on the information from the self-assessment, the research group's evaluation reports, and the interview. The Administrative Unit had the opportunity to fact-check this summary. The Administrative Unit approved the summary.

The Committee judged the information received through documentary inputs and the interview with the Administrative Unit sufficient to complete the evaluation.

List of administrative unit's research groups

Institution	Administrative Unit	Research Groups
Norwegian University of Science and Technology	Department of Mathematical Sciences	Algebra
		Differential Equations and Numerical analysis
		Analysis
		Statistics
		Geometry and Topology

Terms of Reference (ToR) for the administrative unit

The board of the Faculty of Information Technology and Electrical Engineering, NTNU (NTNU-IE), mandates the evaluation committee appointed by the Research Council of Norway (RCN) to assess the Department of Mathematical Sciences, NTNU (NTNU-IMF) based on the following Terms of Reference.

Assessment

You are asked to assess the organisation, quality and diversity of research conducted by NTNU-IMF as well as its relevance to institutional and sectoral purposes, and to society at large. You should do so by judging the unit's performance based on the following five assessment criteria (a. to e.). Be sure to take current international trends and developments in science and society into account in your analysis.

a) Strategy, resources and organisation

b) Research production, quality and integrity

c) Diversity and equality

d) Relevance to institutional and sectoral purposes

e) Relevance to society

For a description of these criteria, see Chapter 2 of the mathematics, ICT and technology evaluation protocol. Please provide a written assessment for each of the five criteria. Please also provide recommendations for improvement. We ask you to pay special attention to the following 4 aspects in your assessment:

1. An analysis of the department's research focus and diversity. Is there an adequate balance between fundamental research and research relevant to industry and the public sector? Are important research topics missing?
2. Are the available economic and human resources compatible with the stated benchmarks for our research groups? What further measures could be taken to support research groups at the highest level?
3. A recommendation for how the department could increase its international visibility and its success in quality-based research competitions.
4. We ask the evaluators to keep in mind that NTNU-IMF takes responsibility for teaching basic courses in mathematics to all NTNU students and in particular to the engineering and technology students which represent the majority of such students in Norway. This extensive service teaching secures valuable income and requires significant, collective effort from the staff of the department.

In addition, we would like your report to provide a qualitative assessment of NTNU-IMF as a whole in relation to its strategic targets. The committee assesses the strategy that the administrative unit intends to pursue in the years ahead and the extent to which it will be capable of meeting its targets for research and society during this period based on available resources and competence. The committee is also invited to make recommendations concerning these two subjects.

Documentation

The necessary documentation will be made available by the mathematics, ICT and technology secretariat at Technopolis Group.

The documents will include the following:

- A report on research personnel and publications within mathematics, ICT and technology commissioned by RCN
- A self-assessment based on a template provided by the mathematics, ICT and technology secretariat
- Research project portfolio overview (internal and external)

Interviews with representatives from the evaluated units

Interviews with the NTNU-IMF will be organised by the evaluation secretariat. Such interviews can be organised as a site visit, in another specified location in Norway or as a video conference.

Statement on impartiality and confidence

The assessment should be carried out in accordance with the *Regulations on Impartiality and Confidence in the Research Council of Norway*. A statement on the impartiality of the committee members has been recorded by the RCN as a part of the appointment process. The impartiality and confidence of committee and panel members should be confirmed when evaluation data from NTNU-IMF are made available to the committee and the panels, and before any assessments are made based on these data. The RCN should be notified if questions concerning impartiality and confidence are raised by committee members during the evaluation process.

Assessment report

We ask you to report your findings in an assessment report drawn up in accordance with a format specified by the mathematics, ICT and technology secretariat. The committee may suggest adjustments to this format at its first meeting. A draft report should be sent to the NTNU-IMF and RCN. The NTNU-IMF should be allowed to check the report for factual inaccuracies; if such inaccuracies are found, they should be reported to the mathematics, ICT and technology secretariat no later than two weeks after receipt of the draft report. After the committee has made the amendments judged necessary, a corrected version of the assessment report should be sent to the board of NTNU-IE and the RCN no later than two weeks after all feedback on inaccuracies has been received from NTNU-IMF.

Appendices

1. Description of the evaluation of EVALMIT
2. Invitation letter to the administrative unit including address list
3. Evaluation protocol
4. Template of self-assessment for administrative unit (short-version)

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