Newton Gateway to Mathematics

Annual Report
2021-2022

UNIVERSITY OF CAMBRIDGE

Isaac Newton Institute for Mathematical Sciences

Mission Statement

The Newton Gateway to Mathematics acts as a vehicle for knowledge exchange between the mathematical sciences and potential users of mathematics, including industry, government, business and other academic disciplines, both in the UK and internationally. It does this by facilitating interactions and activities such as programmes of work, research and training events, as well as bespoke projects. The Newton Gateway to Mathematics aims to widen access to mathematics generally, to shorten pathways to impacts for academic research, and to support education and training in areas where mathematical skills are needed.

What Makes the Newton Gateway to Mathematics Different?

The Newton Gateway to Mathematics is a knowledge intermediary for the mathematical sciences. Although based at the *Isaac Newton Institute for Mathematical Sciences (INI)* and supported by the *University of Cambridge*, the Newton Gateway is an independent body serving the whole of the UK mathematical sciences community and reaches out to and engages with all users of mathematics – in industry, business, public sector and other scientific disciplines. With extensive access to multiple communities across the UK and globally, the Gateway can respond in an agile and flexible manner. It works as a delivery partner to facilitate the exchange, translation and dissemination of knowledge. Using effective communications and proven methodologies, the Gateway develops and runs activities such as workshops and meetings, bringing people and organisations together in order to share knowledge and stimulate further research and collaboration.

Engaging with Users of Mathematics

The Newton Gateway to Mathematics is the impact initiative of the *Isaac Newton Institute for Mathematical Sciences (INI)* based at the *University of Cambridge*. It works with the whole of the UK mathematical sciences community to extend the reach and highlight the importance of mathematics to all potential users such as other academic disciplines and researchers in business/industry and the public sector. User engagement is therefore a key focus, helping to understand the community and end-users in order to collaborate effectively.

The Newton Gateway to Mathematics delivers a range of activities, such as research scoping workshops and knowledge dissemination events across a number of different themes and sectors including biology and healthcare systems, environment and energy, financial risk, security sectors, Big Data and public policy.

Gateway activities have expanded, seeing continued emphasis on partnership and collaboration with other organisations, which is an effective way of engaging with a wider group of stakeholders, helping to reduce duplication. Since March 2020 in response to the *COVID-19* pandemic, the majority of activity has been delivered virtually and the Gateway has explored a number of different technologies to realise this.

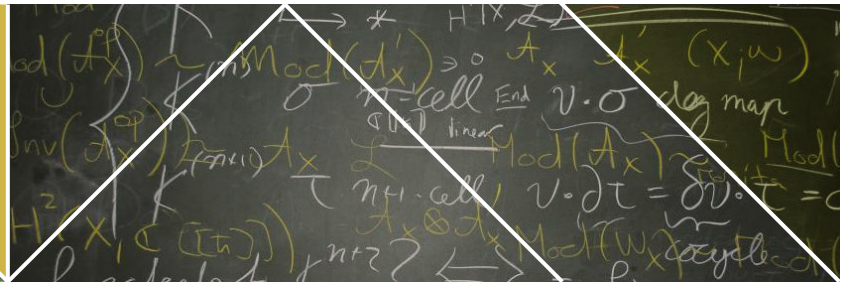
From January 2021 to July 2022, the Gateway led on a specific programme of work to support efforts to model the *COVID-19* pandemic and help guide the UK's response - the *RAMP (Rapid Assistance in Modelling the Pandemic) Continuity Network*. The aim was to ensure scientific networking to develop links with the wider modelling community around *COVID-19*. This helped to create a truly multiscale approach for engagement with those from industry and the public sector. It helped demonstrate the ability of the Newton Gateway to Mathematics to work in partnership, to effectively respond to specific needs, deliver mathematical sciences knowledge exchange and create impact.

In 2019, the Gateway began a programme of work with *Dstl* and *PA Consulting*, with the aim to apply new or alternative mathematical approaches to challenges in the *electromagnetic (EM) environment*. Research workshops took place in 2020, 2021 and 2022 that explored potential solutions to a number of identified challenges and work continued as part of the ongoing delivery of workshops and project activity.

The Gateway has continued in the delivery of the *Edwards Symposium Series* working with the *Edwards Centre for Soft Matter at Cambridge* and supported by *Unilever*. Since 2016, the Gateway has been the user engagement partner for the *Cantab Capital Institute for the Mathematics of Information (CCIMI)* and also works with the *EPSRC Cambridge Mathematics of Information in Healthcare (CMIH)* Hub which was launched in 2020. These partnerships result in the organisation and running of a number of series of events as well as promotion of collaborative opportunities across an expanding community.

As part of all of these collaborations, the Newton Gateway to Mathematics develops programmes of work, disseminates information and develops strategic relationships, to ensure effective translation of science to the user. This has helped partners to understand and gain consensus on the challenges that need to be overcome and facilitate other interdisciplinary collaborations to enrich the existing communities.

Foreword



As for the previous two years, the Gateway continued to face challenges linked to the pandemic and the ongoing uncertainty related to the delivery of in person events. However, resources focused on the opportunities to develop and deliver virtual and hybrid activity with additional flexibility for attendees to attend at shorter notice and from more remote locations. Gateway staff worked remotely for some of the year, but returned to more in person interaction as restrictions lifted and the *Isaac Newton Institute* reopened to staff and then visitors.

Hybrid events have enabled people to attend in person and be joined by others online and this approach has been welcomed as it has facilitated ongoing interaction with those from further afield. A number of events have remained as virtual ones, making use of a wide variety of virtual technologies and networking activities that aim to replicate, as much as possible, the experience of attending a physical event.

Much of Gateway activity has focused on collaborative virtual delivery in response to the *COVID-19* pandemic. The Gateway continued to lead on the *RAMP (Rapid Assistance in Modelling the Pandemic) Continuity Network* which was funded by *UKRI*. This was a specific programme of work to support efforts to model *COVID-19* and help guide the UK's response. The Gateway delivered a series of meetings, workshops and Virtual Study Groups to ensure continuance of relevant research and scientific networking. This helped maintain strong communication links and further develop engagement with the wider modelling community, as well as other mathematicians and those from industry and the public sector – particularly policymakers.

Within this activity, the Gateway developed a number of scientific meetings that focused on emerging priorities related to *COVID-19*, including *Optimal Vaccination Strategies; Epidemic Models: Insights from the RAMP Project*; *Controlling COVID-19 in Schools*; and *Asymptomatic Testing and COVID-19*. A number of these were events that reflected back on models that had been developed, to help identify lessons learned and planning for future eventualities. In addition, a number of *Virtual Study Groups* took place which focused on economic recovery from the pandemic, looking at aspects related to *Hospitality & Leisure*; *Post COVID-19 Recovery - Communities of the Future*; *Transport Logistics*; and *Public Perception of Science*.

More information about *RAMP* can be read later in this Annual Report, but one notable event was *Modelling Behaviour to Inform Policy for Pandemics*, which took place in November 2021. During the pandemic, modelling took centre stage both in forecasting, policy formulation and in informing the public. The pandemic has had profound influence on social and economic activity, meaning that different policy interventions such as lockdowns and furlough schemes cannot be seen as merely public health policies or as economic policies in isolation. This series of half day science meetings brought together the relevant scientific communities with those involved in policy formation to maximise the potential for interaction and collaboration. Modellers and policymakers explored how to assess how different interventions were likely to play out in practice, but also guided the policy making process itself, indicating which policies were likely to lead to greater health and socio-economic wellbeing.

The Gateway's role in *V-KEMS* (the *Virtual Forum for Knowledge Exchange in the Mathematical Sciences*) remained a priority, identifying a range of virtual approaches to help address challenges from business and industry, the third sector, and other groups outside academia. Most of the challenges that have been explored resulted directly as a consequence of the disruption to UK society caused by *COVID-19*. *V-KEMS* delivery has been a truly collaborative programme including supporting the delivery and development of the Virtual Study Groups as part of the *RAMP* activity. In November 2021, *V-KEMS* was awarded "*KE Team of the Year*" at the annual *PraxisAuril KE Awards 2021*.

The Gateway has continued to deliver user engagement for *CCIMI (Cantab Capital Institute for the Mathematics of Information)* – with two events – one with an academic focus and the other aimed at highlighting the industrial collaboration of the Institute. The *EPSRC Cambridge Mathematics of Information in Healthcare (CMIH)* Hub was launched in 2020 and the Gateway delivered two events this year encouraging industrial interaction related to mathematical healthcare data analytics across the UK, with mathematicians working in similar areas.

The programme of work with *DstI* and *PA Consulting* concluded, having helped achieve the aim to apply new or alternative mathematics to challenges in the *electromagnetic (EM) environment*. A final Virtual Study Group took place in January 2022, where a number of specific challenges were worked on – leading to innovative potential solutions being presented.

In March 2022, the Gateway was appointed as a new Partner in *UKRI's Analysis for Innovators Programme A4I*. This is a programme that gives UK businesses of any size access to cutting-edge R&D expertise and facilities to help solve problems that they have been unable to tackle using standard technologies and techniques. Academics from the Gateway *Scientific Advisory Panel* or those associated to it, provide input to

A4I activities and are taking forward a number of projects with individual companies.

Previous reports have highlighted the proposal to set up a *Knowledge Exchange Connected Centres Network (CCN) for Mathematical Sciences* following Philip Bond's 2018 publication of the *Era of Mathematics: An Independent Review of Knowledge Exchange in the Mathematical Sciences*. Following consultation over the past year, a *Knowledge Exchange Manager*, Rachael Harris, was appointed in July 2022 for the development and delivery of the new *Knowledge Exchange Hub for the Mathematical Sciences (KE Hub)*.

The *KE Hub* will scale up and accelerate Knowledge Exchange activity in the mathematical sciences in the UK, building on the existing mathematical sciences infrastructure. The Gateway will work with the *KE Hub* as it develops to explore opportunities for collaboration to support the mathematical sciences community in the UK.

The Gateway and *INI* have provided support to the *UKHSA's Mathematical Modelling PhD Student Placements* scheme. This sought to hire six PhD students to work in 2 multi-disciplinary analytical directorates that were at the forefront of the response to *COVID-19*. These 3-month internships were open to PhD students with strong mathematics and statistics backgrounds. As well as work experience, the placement also provided the candidates a pastoral and development programme, together with opportunities for technical skills development.

Through ongoing engagement activity, the Newton Gateway has continued to extend its reach across different sectors. The ability to engage in a virtual and hybrid manner has enabled increased numbers of participants to attend Gateway events offering greater opportunities for interaction between those in industry, the public sector and academia, often for individuals who have not worked together previously. Activities have been delivered in partnership with other organisations, as detailed within this Annual Report, which has ensured further collaborative opportunities with new connections made across a breadth of sectors and subjects.

The Newton Gateway to Mathematics is very grateful for the support given by *INI*, the *University of Cambridge* and our colleagues, partners and stakeholders, particularly in relation to ongoing challenges related to the pandemic. We have been in the fortunate position to continue to work effectively in novel virtual and hybrid ways and have ensured continued delivery of partnership activity. The Gateway will celebrate its tenth anniversary in 2023, and we look forward to working with new stakeholders and welcoming participants at our events at INI and elsewhere.

Staff and Management

Responsibility for the budget and financial planning is overseen by *INI's Management Committee* and undertaken on a day-by-day basis by Newton Gateway staff. The Gateway reports to the INI Director who in turn is responsible to the *Management Committee*.

The Newton Gateway is supported in delivering activity by the *Gateway Advisory Board* and *Scientific Advisory Panel*, who advise on programmes and activities and help with quality assurance in aspects of delivery and operations. The key aim is to help ensure that the highest levels of delivery and operations are achieved throughout Gateway activity and its effectiveness is fully maximised.

Newton Gateway to Mathematics Staff (at July 2022)

The **Gateway Manager**, Jane Leeks, has overall responsibility for managing the Gateway and for developing contacts with mathematical and non-mathematical academics, with industry, business and public sector. This role is pivotal in identifying potential research and collaborative opportunities of mutual benefit to mathematicians and end-users, such as industry, business and Government.

The **Senior Knowledge Exchange Coordinator**, Clare Merritt, supports diversification of Newton Gateway to Mathematics activities, coordinates and develops events and marketing activity with industry and businesses. Clare leads some specific programmes of work, including user engagement on behalf of Newton Gateway to Mathematics Partners and A4I. Clare leads on Gateway Governance.

The **Scientific Knowledge Exchange Coordinator**, Dr Maha Kaouri, provides technical research and knowledge exchange support to Gateway activities. This involves scientific and technical exploration and analysis of the Gateway delivery, in particular the translation and dissemination of scientific details and information to a broader audience.

The **Events and Marketing Coordinator**, Claire Bonner leads on the day-to-day coordination of events and related activities. Claire supports the development and delivery of Gateway events and marketing activity as well as providing financial management and administration.

The **Events and Marketing Assistant**, Noemi Carofano provides support to the Gateway for the day-to-day coordination of events and related activities.

Governance

The **Newton Gateway to Mathematics *Advisory Board*** has Members from industry and public bodies to help advise on strategic matters and on the overall development of the Newton Gateway to Mathematics.

Members have helped to facilitate the delivery of a number of activities and programmes of work and act as "Ambassadors" for the Gateway in discussion and interaction with other partners.

The Board meets twice a year in Cambridge. The Chair is invited to attend *INI Management Committee* meetings to provide supplementary reporting on Gateway activity and delivery.

Advisory Board Membership (at July 2022):

Name	Organisation
Matt Butchers	Department for Business, Energy and Industrial Strategy (BEIS)
Alan Champneys	Representative of Gateway Scientific Advisory Panel
Nick Easton	BAE Systems Applied Intelligence
Joanna Jordan	Freelance Mathematics Knowledge Exchange
Peter Landrock (Chair)	Cryptomathic
Jane Leeks	Newton Gateway to Mathematics - Manager
Robert Leese	Smith Institute
Clare Merritt	Newton Gateway to Mathematics – Governance Lead
Dan Shepherd	National Cyber Security Centre
Sian Thomas	Department for International Trade
Stacie Tibos	PepsiCo International
Ulrike Tillmann	Isaac Newton Institute - Director
Dawn Wasley	International Centre for Mathematical Sciences (ICMS)

The **Newton Gateway to Mathematics *Scientific Advisory Panel*** provides input and guidance on specific scientific or research matters related to Newton Gateway to Mathematics activities. Members are all academics and operate largely in a virtual capacity via email and telephone and are responsive to ad-hoc questions and requests for guidance from the Newton Gateway to Mathematics.

The Chair is invited to attend Newton Gateway to Mathematics Advisory Board meetings.

All Members of the *Scientific Advisory Panel* are invited to meet with the *Advisory Board* every 12 months to ensure they have the opportunity to input more strategically to the range and nature of Newton Gateway to Mathematics activities.

Membership is regularly reviewed to ensure it reflects the breadth of disciplines that the Gateway can work on and a fuller geographical spread of representation by Members.

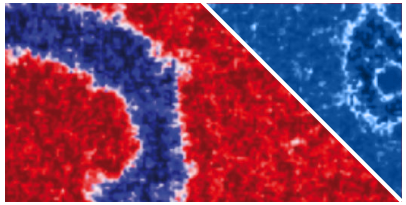
Scientific Advisory Panel Membership (at July 2022):

Name	Organisation
Philip Aston	University of Surrey
Martine Barons	University of Warwick
Chris Breward	University of Oxford
Peter Challenor	University of Exeter
Alan Champneys (Chair)	University of Bristol
Christine Currie	University of Southampton
Chris Dent	University of Edinburgh
Rosemary Dyson	University of Birmingham
Jacek Gondzio	University of Edinburgh
Des Higham	University of Edinburgh
Rebecca Hoyle	University of Southampton
Jane Hutton	University of Warwick
Arieh Iserles	University of Cambridge
William Lee	University of Huddersfield
Gabriel Lord	Radboud University (and Heriot-Watt University)
Anotida Madzvamuse	University of Sussex
Adele Marshall	Queen's University Belfast
Jeremy Oakley	University of Sheffield
Surajit Ray	University of Glasgow
Nigel Smart	KU Leuven
Manuchehr Soleimani	University of Bath
Emily Walsh	University of the West of England
Adrian Weller	University of Cambridge

Gateway Activities from August 2021 – July 2022

8 – 10 September 2021

5th Edwards Symposium – Future Directions in Soft Matter



2021 was the fifth year in the *Edwards Symposium Series* which was set up as a tribute to the life and work of Professor Sir Sam Edwards FRS, one of the great scientific minds of the 20th Century. The event highlighted the latest developments in soft matter science with a particular (but not exclusive) emphasis on theoretical and mathematical models, and on how these models can inform industrial processes, materials, and design.

Talks focused on polymer melt dynamics and process rheology, informatic approaches to soft matter, functional gels and energy materials and soft matter for sustainable foods. These themes posed fundamental questions in basic science that were addressed by distinguished academic speakers and their industrial relevance was reflected by industrial participants whose presentations and posters informed the discussions. The series has been funded in part by ongoing generous support from Unilever, which continues until 2022. The Symposium took place in a hybrid format – taking into account that not all individuals were able to travel.

3, 10 and 17 November 2021

Machine Learning Training for Industry

The Newton Gateway has implemented a number of short intensive training courses in mathematical areas of relevance to individuals in industry, business and government. These courses provide technical training in the subject matter with the emphasis on practical applications of mathematics.

The first training focused on machine learning and provided 12 delegates from industry with essential skills in implementing machine learning algorithms for clustering, classification and predictive analytics using Python programming language and its ecosystem of machine learning libraries including (but not limited to) statsmodels, scikit-learn, h2o and SciPy. It took place over 3 days in a hybrid teaching format and was delivered in collaboration with *Mind Project*. Feedback from attendees helped highlight additional topics where training could be developed and delivered in future years.

24 November 2021

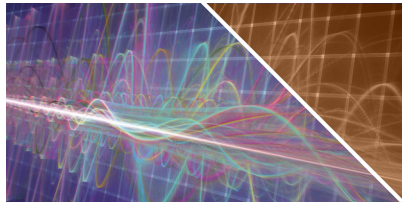
Cantab Capital Institute for the Mathematics of Information – Industry Engagement

This half day annual Industry engagement event of *Cantab Capital Institute for the Mathematics of Information (CCIMI)* brought together academics and those from industry working to advance data science. It aimed to showcase the research that is being carried out at the Institute and enabled delegates to hear more detail about some of the current project collaborations and industry challenges that *CCIMI* is exploring.

It highlighted other potential collaborative opportunities, as well as projects being developed elsewhere related to data analysis. *CCIMI* was pleased that it was delivered in a hybrid format with opportunities for physical and virtual posters to be displayed as well as online discussion and interaction.

12 – 14 January 2022

New Mathematical Challenges in the Electromagnetic Environment

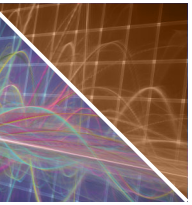


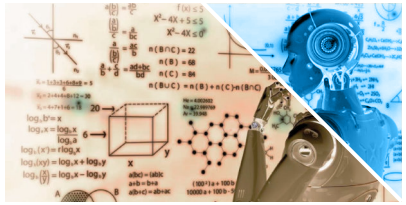
The Newton Gateway began a programme of work in 2019 with *Dstl* and *PA Consulting*, with the aim to apply new or alternative mathematics to challenges in the *electromagnetic (EM) environment*. Operating in the *EM environment* has become increasingly complex due to continuing growth in civilian and military demand for spectrum (for example 5G), which has made it a highly congested and contested area. Current approaches to solving the challenges of operating in this environment have been successful over many years, but this increased complexity means it is now necessary to explore innovative approaches.

This three-day study group gave participants the opportunity to explore a number of new challenges in depth during break-out sessions. Participants for this study group came from a number of diverse fields including signal processing, optimisation, operational research, imaging and vision, control theory, wave theory, machine learning and electrical and communications engineering. Mathematicians who would not normally be involved in electromagnetics were encouraged to join, with the event taking place in a hybrid format to help enable this.

28 February – 4 March 2022

LMS Invited Lectures on the Mathematics of Deep Learning



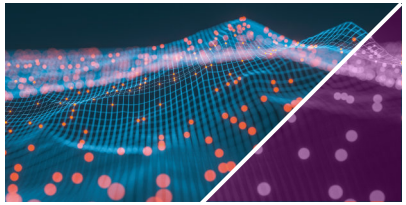


This workshop aimed to provide a mathematical foundation of deep learning by giving an introduction to the main mathematical questions and concepts of deep neural networks and their training. It focused upon the *Theoretical foundations of deep learning independent of a particular application*, and *Theoretical analysis of the potential and the limitations of deep learning for mathematical methodologies*, in particular, for inverse problems and partial differential equations.

The workshop featured an introductory lecture series across the week, by Professor Gitta Kutyniok *(LMU, Munich)* on the mathematics of deep learning. Four accompanying lectures were given by Peter Bartlett *(University of California, Berkeley)*, Weinan E *(Princeton University)*, Klaus-Robert Müller *(Technische Universität Berlin)* and Rebecca Willett *(University of Chicago)*. it was delivered in a hybrid format with attendees able to interact in person and virtually over the week. The event was developed and delivered in partnership with the *LMS (London Mathematical Society)* and *INI*.

3, 10 and 17 May 2022

Optimisation Training for Industry



The Newton Gateway continued to implement a number of short intensive training courses in mathematical areas of relevance to individuals in industry, business and government. These courses provide technical training in the subject matter with the emphasis on practical applications of mathematics.

This second training course focused on Optimisation, which is an Operational Research methodology that provides solutions to real-world decision problems across a wide range of application areas. Optimisation is concerned with finding the "best" solution to a problem that has a large number of possible solutions. The aim was that on completion of the course, the 25 participants would have an understanding of optimisation methods and their use to solve decision making problems. Participants became familiar with strengths and limitations of different optimisation approaches. The event was delivered in collaboration with *NATCOR*.

4 May 2022

Cambridge Mathematics of Information in Healthcare Hub (CMIH) Industry Round Table Afternoon

The *EPSRC Cambridge Mathematics of Information in Healthcare (CMIH)* Hub was launched in 2020. It focuses on some of the most challenging public health problems of our time, including Cancer, Cardiovascular Disease and Dementia. There is a core mathematical component that is common to data challenges across these clinical disciplines, which the Hub will evaluate and address through its interdisciplinary collaborations. The overarching objective is to develop data analytics algorithms and provide the associated theory that is directly linked to the requirements in the clinic for healthcare decision making.

This focused engagement event featured presentations from *CMIH* researchers followed by facilitated discussion with *CMIH* industry partners to explore opportunities for new collaborations and engagement. Talks focused on the key theme of the *CMIH Hub*, which is the development of robust and clinically applicable algorithms for analysing healthcare data in an integrated fashion. The event helped to reinvigorate collaborative engagement opportunities between industry and academia.

26 May 2022

Uncertainty Quantification: Recent Advances in the Mathematics of Information

The *Cantab Capital Institute for the Mathematics of Information (CCIMI)* held its sixth annual academic conference, which focused on the academic advances in the mathematics of information.

The conference brought together those academics working to advance data science and provided an update on the research and collaborations taking place at *CCIMI* specifically related to uncertainty quantification. Additionally, it highlighted other potential collaborative opportunities, as well as projects being developed elsewhere related to data analysis.

There was a session of short "elevator pitches" from next generation researchers as well as a poster session by some registered delegates. Poster prizes were given to two participants, sponsored by the Royal Statistical Society.

The event was held in person, which enabled full engagement opportunities, although virtual attendance was still facilitated for a number of academic and industry partners.

12 – 15 July 2022

UK Graduate Modelling Camp

The annual *UK Graduate Modelling* camp took place in person in partnership with the *Industrially Focused Mathematical Modelling (InFoMM) Centre for Doctoral Training* at the *University of Oxford*. The camp was open to all PhD students and designed to promote a broad range of problem-solving skills, such as mathematical modelling & analysis, scientific computation & critical assessment of solutions. It provided participants with hands-on experience of mathematical modelling under the guidance of experienced instructors and mentors.

Over the four days, the students worked on challenges that were inspired by real-world challenges that had arisen in industry or science. Scientific communication was an important part of the camp and all participants were expected to make presentations. Prizes were awarded by Erica Tyson of the *IMA*, the Director of *InFoMM* (Professor Chris Breward) and the Newton Gateway for the Best Group Presentation (awarded to the *Neutralising Toxic Chemicals in Porous Media* group) as well as the Top Student from each of the five groups. A special 'Gallantry Prize' was awarded to Aldaïr Petronilia *(University of Oxford)* for his courteousness.

26 July 2022

Cambridge Mathematics of Information in Healthcare Hub (CMIH) – Academic Engagement Event

This academic event of the *CMIH Hub* brought together those working in mathematical healthcare data analytics across the UK, including academic, clinical, and industrial users with mathematicians working in similar areas.

Talks focused on the key theme of the Hub, which is the development of robust and clinically applicable algorithms for analysing healthcare data in an integrated fashion. It included talks that highlighted open challenges and successes from *CMIH Hub* researchers and presented other potential collaborative opportunities, as well as projects being developed elsewhere related to healthcare data analytics.

In addition, partner *EPSRC Hubs for Mathematical Sciences in Healthcare*, gave presentations on progress since their launch in 2020.

27 – 29 July 2022

Medical Image Understanding and Analysis 2022

MIUA 2022 (Medical Image Understanding and Analysis) was a UK-based international conference for the communication of image processing and analysis research and its application to medical imaging and biomedicine.

The event helped to communicate research progress within the community interested in image analysis applied to medicine and related biological science. The meeting was designed for the dissemination and discussion of research in medical image understanding and analysis and aimed to encourage growth and raise the profile of this multi-disciplinary field by bringing together the various communities.

MIUA 2022 welcomed over 200 researchers in medical imaging including mathematicians, computer scientists, bioinformaticians, clinicians, engineers and bioscientists. The Gateway helped to deliver the event as part of the local organising committee, working to ensure that this was a truly collaborative engagement activity.

RAMP Continuity Network:

Scientific Meetings, Rapid Review Group, and Policy Support for COVID-19

From March 2020, *The Royal Society* used its convening power to support efforts to model the *COVID-19* pandemic and help guide the UK's response. In particular, it set up the *Rapid Assistance in Modelling the Pandemic (RAMP)* initiative and the *Data Evaluation and Learning for Viral Epidemics (DELVE)* group. *RAMP* brought modelling expertise from a diverse range of disciplines to support the pandemic modelling community already working on *COVID-19*.

From January 2021 until July 2022, the Newton Gateway played a key role in the follow-on *UKRI* funded project. The *RAMP Continuity Network* helped to support efforts to model the *COVID-19* pandemic and helped to guide the UK's response. The Gateway delivered a series of meetings, workshops and Virtual Study Groups to ensure scientific networking to help maintain strong communication links and further develop links with the wider modelling community around *COVID-19*. This has helped to create a truly multiscale approach and ensured engagement between the mathematical community as well as with those from industry and the public sector.

The Gateway developed a number of short meetings that reacted to key priority areas in the UK's response to the current pandemic. These reflected and shared details of the key emerging issues, discussions, and expertise that were being developed, exploiting new data as available. These meetings set agendas to help provide rapid-response support, engaging with the wider modelling community. These events were guided by links with groups including the *JUNIPER (Joint UNIversities Pandemic and Epidemiological Research)* consortium to ensure their relevance to current UK policy and engage with the wider mathematical modelling and epidemiology communities.

The *JUNIPER* consortium, set up in autumn 2020, is a network of academic research groups from across the UK who generated forecasts, predictions and insights that fed into scientific advice to the UK government on the UK's response to the *COVID-19* pandemic. Working with the Gateway through the *RAMP* activities allowed *JUNIPER* to engage with the wider mathematical modelling community, identifying novel areas of research and allowing the network to develop new links with previously disparate areas of mathematical modelling.

The Gateway also developed a number of scientific meetings that further developed those taken forward by different Task Teams as part of the *RAMP* initiative. Specific topics emerged over the period of the project, including developing epidemic models, modelling behaviour to inform policy for pandemics and developing optimal vaccination strategies. The Gateway worked alongside Early Career Researchers who specialised in these topics to aid in the development of the science meetings, with the view that they could not only bring invaluable scientific knowledge to enhance the quality of the events, but also gain some experience in knowledge dissemination in the process.

Virtual Study Groups linked to *RAMP* continued to take place. These were developed and delivered in partnership with *V-KEMS* partners, including the Gateway, *ICMS* and the *KTN*. Unlike in earlier study groups where the main focus was on modelling the spread of the infection, the ones developed over this reporting period focused on recovery from the pandemic across a number of different sectors and included presentations and then modelling on a number of different challenges.

Following each study group, a summary report was produced for each challenge presenter. These were developed by Early Career Researchers. A longer and more detailed report was produced within the months that followed. Some other outcomes included an on-going collaboration between a Postdoctoral Researcher from the *University of Oxford* and *The Royal Opera House* and a *Santander* Scholarship-funded Summer Internship at the *University of Bath* with *Shakespeare's Globe*, which built on the work of the *Recovery from the Pandemic: Hospitality & Leisure – Virtual Study Group*. Following the success of the *Public Perception of Science – Virtual Study Group*, an in-person follow on event will be held on *Communicating Mathematics for the Public* in early 2023.

RAMP Activities from August 2021 – July 2022

12 - 14 October 2021

Recovery from the Pandemic: Hospitality & Leisure – Virtual Study Group

This three-day virtual study group run by *V-KEMS* brought mathematical scientists and other disciplines together to solve challenges faced by the hospitality and leisure sector as a result of the *COVID-19* pandemic. The UK leisure industry as a whole was met with some unprecedented challenges over the course of the pandemic and will continue to do so as the nation recovers.

The event theme was about recovery from the pandemic with a focus on dealing with the operational difficulties and economic implications which have arisen. It used mathematics as a tool to help solve the particular challenges hotels, restaurants and leisure facilities, such as cinemas, theatres and gyms, are facing as a result of the pandemic. Ventilation of indoor facilities, audience/ customer risk perception and scheduling/ resource management were modelled. Since the event, participants have collaborated to develop a working paper which can be seen on the Gateway *RAMP* webpages.

2 – 5 November 2021

Modelling Behaviour to Inform Policy for Pandemics

Over the course of the *COVID-19* pandemic, modelling has taken centre stage both in forecasting, policy formulation and in informing the public, featuring prominently in the advice given to government in the UK and beyond. The pandemic has had profound influence on social and economic activity, meaning that different policy interventions such as lockdowns and furlough schemes cannot be seen as merely public health policies or as economic policies in isolation. It is therefore important to better understand how policies interact through intertwined economic and disease dynamics and how different policies must be designed to work together.

This event brought together both modellers and policymakers to not only assess how different interventions will likely play out in practice, but also guide the policy making process itself, indicating which policies are likely to lead to greater health and socio-economic wellbeing.

14 December 2021

Optimal Vaccination Strategies

The huge impact of the *COVID-19* pandemic across the globe was met by heroic efforts from the entire scientific community - developing vaccines and delivering them in the most effective manner in order to minimise disease burden and reduce the reliance as much as possible on socially damaging non-pharmaceutical interventions. With quantity and deployment speed of vaccines initially limited, the question of optimal deployment strategy and who to target first, has and continues to be of great importance for policy makers across the globe.

This one-day virtual workshop took into account the complexities and intrinsically linked issues of who to target with the vaccine and how this then fits within a global context. It considered important factors such as the effects of variants which are still emerging and issues around vaccine sharing. Scientists from a number of disciplines as well as the mathematical sciences presented talks highlighting the latest state-of-the-art research which can contribute to modelling optimal vaccination strategies. Important modelling approaches including optimal control theory and game theory amongst others were presented.

8 – 10 February 2022

The Role of Uncertainty in Mathematical Modelling of Pandemics

There is an urgent need to advance the reliability and reproducibility of all forms of computer-based calculations. In an experimental setting, it is often common practice to provide not only measured values themselves, but also an estimate of the uncertainty in the measurements. However, this is not yet standard practice when presenting predictions made by computational models.

Computational methods are becoming increasingly important for decision-making and thus a similar approach is needed to make computational predictions actionable, since virtually all models are contaminated by several sources of uncertainty. Sources of uncertainty originate in the imperfectly known input parameters assumptions made within the mathematical form of the model, and the influence of stochastic effects.

The event series focused on uncertainty modelling for epidemiology and pandemics and highlighted new opportunities for simulations in fields as diverse as fusion, weather and climate modelling, advanced materials, biomedicine and many other domains. It was developed with members of the *EPSRC*-funded *SEAVEA* project.

22 February 2022

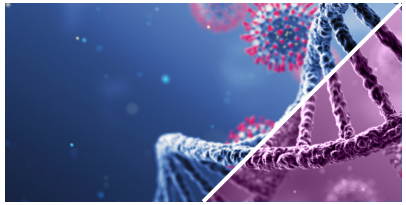
Behaviour and Policy During Pandemics: Models and Methods

This event followed an earlier 3-day event that took place in November 2021, which had brought together modellers and policymakers to not only assess how different interventions will likely play out in practice, but also guide the policymaking process itself, indicating which policies are likely to lead to greater health and socio-economic wellbeing.

This virtual workshop, delivered in partnership with the *JUNIPER* consortium, brought together the relevant scientific communities (epi-modellers and economic epidemiologists) to work on addressing current problems in modelling behaviour and its epidemiological, economic and societal implications for the *COVID-19* pandemic. A number of different challenges were posed, followed by the opportunities for discussion and the identification of possible next steps.

15 March 2022

Genomic, Evolutionary and Epidemiological Approaches for Pandemics

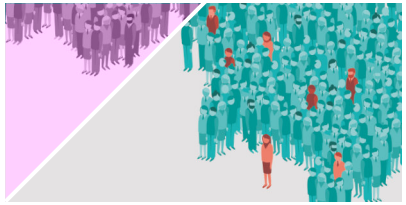


Genomics and evolutionary biology now provide major tools used in the surveillance and study of infectious diseases. However, to a large extent, the communities involved in genomic surveillance and traditional epidemiological modelling speak different languages, and this limits their interaction.

This one-day virtual workshop facilitated communication between epidemiological modellers and computational and evolutionary biologists. This was achieved by giving an overview of important topics in pathogen evolution and adaptation, as well as discussing tools available to merge epidemiological and genomic data and providing case studies of their use in the infectious disease research. Participants had the opportunity to raise questions following each presentation. There was also a facilitated Q&A discussion at the end of the day where individuals tabled further questions and shared thinking.

23 – 24 March 2022

Epidemic Models: Insights from the RAMP Project



Better understanding of the transmission of *COVID-19* is a key factor in managing risk and designing practical interventions. These 2 half-day events included talks by those who, via the *RAMP* project or otherwise, realigned their research to focus on human epidemic modelling after the *COVID-19* pandemic had begun. Speakers presented highlights of modelling that took place, as well as giving updates where this continued. There was opportunity for participants to pose some questions to help push the field further forward more broadly.

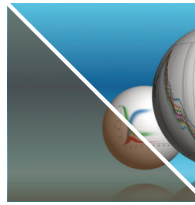
Talks explained how well models performed earlier in the pandemic, providing an update on more recent progress and identifying some useful learning for modellers going forward. A number of different models were presented highlighting methodological developments and applications to various datasets.

29 – 31 March 2022

Recovery from the Pandemic: Transport Logistics – Virtual Study Group

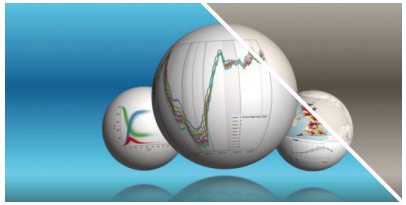
This three-day virtual study group run by *V-KEMS* brought together mathematical scientists and other disciplines including mathematical modelling, statistics, operations research, logistics and supply chain management to solve end user defined challenges in transport logistics. The aim was to mitigate the impact of *COVID-19*, climate change and the change of regulations on the shipping and supply chain network.

Increased border restrictions, a reduction in the availability of workers and the increased demand for home delivery over the past 2 years has meant that the freight transport network has had to drastically adapt its operations. The consequent impact on the supply chain has been substantial and can be observed by simply looking at supermarket shelves. A number of different problems were posed and potential solutions were developed.



5 April 2022

Socio-Economic Determinants of Coronavirus in the UK



The transmission dynamics of infectious diseases are inevitably influenced by inequality, poverty and social determinants of health. Health disparities or inequalities will result in unequal burdens across a country's population in terms of economic impact, morbidity and mortality. The *COVID-19* pandemic is no exception, arguably highlighting and perhaps widening decades of health inequalities.

This one-day virtual workshop aimed to facilitate communication between epidemiologists, social scientists, mathematical modellers and public health policymakers. It did this by giving an overview of the emerging socio-economic patterns seen through the lens of the UK *COVID-19* public health data, as well as discussing the socio-economic factors from both a public health and social science perspective.

27 April 2022

Controlling COVID-19 in Schools: Lessons Learned and Open Questions

The control of *COVID-19* within the school setting poses a unique challenge. While policymakers must consider the impact that uncontrolled transmission within schools may have on transmission within the community at large, they must also consider the impact of restrictions to reduce within-school transmission on pupil absences, educational attainment and other factors.

Since the beginning of the *COVID-19* pandemic, a range of control measures have been introduced to control transmission in schools, from mask-wearing to regular mass testing to the isolation of close contacts. Correspondingly, a range of studies and approaches have been used to understand the effectiveness and impact of different control measures, from modelling studies to randomised controlled trials. Understanding the true impact of different measures is paramount to the design of effective control measures within the school setting. This session aimed to synthesise what had been learnt about the impact of *COVID-19* in the school setting and to identify the gaps in knowledge that are vital to answer going forward to plan better school-level control policies for future pandemics. It was delivered in partnership with the JUNIPER consortium.

18 – 20 May 2022

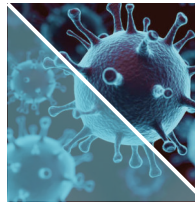
The Public Perception of Science – Virtual Study Group

The *COVID-19* pandemic has impacted many lives of people across the world. This has meant that now more than ever, the public is keen to (and has a need to) know the latest and most accurate science. In addition, scientists are under immense pressure to not only produce quality research under tight timescales, in order to help the UK government form policies and make decisions, but also to communicate their findings to audiences from both scientific and non-scientific backgrounds, both on television, radio and on social media platforms.

This three-day Virtual Study Group aimed to bring mathematical scientists and other disciplines together to solve end user defined challenges related to trustworthy communication, communicating mathematics and misinformation. Challenges were presented by *The Winton Centre*, *The Times* and the *Office for Statistics Regulation*.

7 June 2022

Asymptomatic Testing and COVID-19: A Retrospective Assessment and Lessons Learned

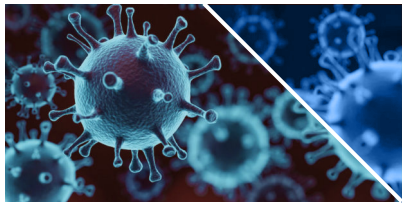


This one-day in-person event took a retrospective look at asymptomatic testing during the *COVID-19* pandemic, as well as a forward look on what lessons could be learned to help the research community develop better models and government make better policy decisions in the future.

The event brought together those that worked at the forefront of the response to the pandemic to present work on how asymptomatic testing helps reduce transmission. Talks covered the role of testing in controlling *COVID-19* in education, healthcare and work settings; and challenges and opportunities in predicting the impact of asymptomatic testing for future variants or novel infectious diseases. Each of the sessions consisted of talks with time for questions from the audience.

13 June 2022

Modelling the COVID-19 Pandemic: Achievements and Lessons



The *Royal Society, RAMP Continuity Network*, the *Isaac Newton Institute*, Gateway and the wider modelling community reflected on the scientific and policy implications of modelling work done in response to the *COVID-19* pandemic and celebrated the role of Early Career Researchers in that response. The event, held at the *Royal Society* in London, brought together the wide community of modelling scientists involved in the *COVID-19* pandemic response to celebrate their contributions.

The first part of the day consisted of a series of talks by Early Career Researchers across modelling disciplines relevant to the pandemic response. This was followed by a policy-focused panel discussion which explored the lessons from the pandemic on how the scientific community can respond to future emergencies. The event closed with a series of public talks from invited speakers which provided an overview on epidemiological modelling, the factors that influence virus transmission and the path between science and policy.

23 – 23 June 2022

Modelling to Support Resilience for Pandemics – Open Questions

This two-day in-person event aimed to highlight and reflect on lessons learned from the modelling undertaken during the *COVID-19* pandemic. Talks and discussions explored the key epidemiological questions - how could these be answered, what models fit these areas and how could these be used to build systems to strengthen resilience for the future.

Talks highlighted successes and lessons learned and helped identify future steps to build resilience. The event was delivered in partnership with the *JUNIPER* consortium and was the final event in the *RAMP* continuity programme of work that the Gateway had delivered since January 2021.

More information on *RAMP* activity can be found on the webpage https://gateway.newton.ac.uk/ramp

Virtual Forum for Knowledge Exchange in the Mathematical Sciences (V-KEMS)

Since March 2020, the Gateway has been helping to develop, deliver and support activity by *V-KEMS (Virtual Forum for Knowledge Exchange in the Mathematical Sciences)* which was established in response to the *COVID-19* pandemic. The *Newton Gateway to Mathematics, Isaac Newton Institute (INI), International Centre for Mathematical Sciences (ICMS)* and *Knowledge Transfer Network (KTN)* have worked with various representatives from the mathematical sciences community to develop this virtual forum. The main aim has been to identify a range of virtual approaches to help address challenges from business and industry, the third sector, and other groups outside academia. These challenges may have been long-standing or may have arisen directly as a consequence of the present disruption to UK society.

Many initiatives were already taking place to help provide infrastructure and resources to clinicians and others who were urgently helping to model the current pandemic. Where appropriate, *V-KEMS* has provided direct support to this activity. However, *V-KEMS'* main focus has been to identify broader areas for input from the mathematical sciences community – for example tackling issues related to food supply and logistics etc.

V-KEMS activity over the reporting period has involved developing and delivering a number of Virtual Study Groups linked to *RAMP* continuity that has already been highlighted. These focused on recovery from the pandemic for a variety of different sectors, around recovery from the pandemic for a variety of different sectors.

Activities

A number of activities have been taking place:

- **Virtual Study Groups** - activity has focused on the development and delivery of Virtual Study Groups – a number of which have input directly to advice being developed by officials who have been working with Government in response to *COVID-19*.
- **Webinars/Scoping Meetings** - providing the infrastructure to host appropriate webinars and scoping meetings online.
- **Mathematical Support to Business, Industry, the Public and Third Sectors** - where industry, business, the public sector or the third sector have an identified problems that would benefit from mathematical input.

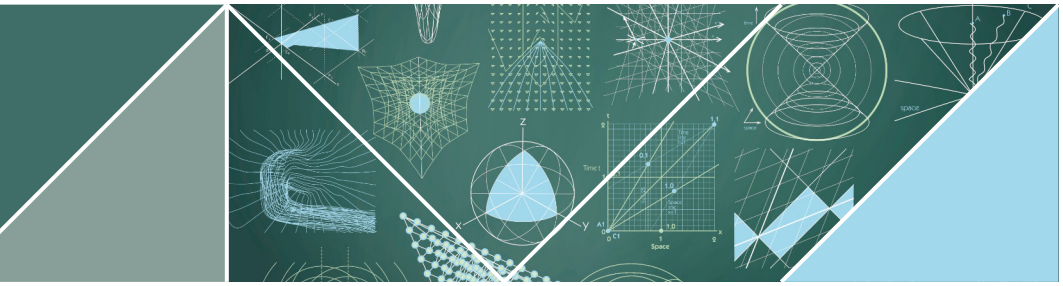
In November 2021, *V-KEMS* was awarded *"KE Team of the Year"* at the annual *PraxisAuril KE Awards 2021*. *PraxisAuril* is the UK's professional association for Knowledge Exchange practitioners, with its range of annual awards representing the highest accolade of industry recognition within the sector.

The 2021 virtual "black tie" awards ceremony took place on the afternoon of Thursday 20 November 2021, with the 17 shortlisted finalists picked from a pool of 60 overall entrants being invited to attend. Each finalist was invited to give a short summary of their group's achievements before the winners in each of the six categories were announced.

V-KEMS beat two other candidates to the title. The award was presented by Simon Bond *(Innovation Director, SETsquared Partnership)*. The Awards were sponsored by *UKRI*, the UK's research and innovation funding body. Matt Butchers from the *KTN* accepted the award on behalf of all the *V-KEMS* partners.

More information on *V-KEMS* activity can be found on the website www.vkemsuk.org and through its Twitter account www.twitter.com/V_KEMS

Knowledge Exchange Activities for INI Research Programmes



The *Isaac Newton Institute* sponsors Knowledge Exchange activity, referred to as *'Open for Business' (OfB)* knowledge exchange events, as a part of its continuing objective of bringing academic researchers involved with its research programmes into contact with industrial, commercial and government organisations and individuals. These activities, which are delivered by the Newton Gateway to Mathematics, provide opportunities for cross-fertilisation between the activities of users from industry and the public sector, and the research focus of the Institute. *OfB* events are structured to enable the formation of new public-private partnerships, collaborative research and to assist in identifying the common challenges that have greatest potential for research, knowledge exchange, public policy and commercial impact.

In this reporting year no *OfB* events took place because of the *COVID-19* pandemic. However, planning for the development and delivery of events for later in 2022 and early 2023 are in hand.

Activities to Support National Initiatives

Knowledge Exchange Hub for Mathematical Sciences (KE Hub)

In 2018 Professor Philip Bond published the *Era of Mathematics: An Independent Review of Knowledge Exchange in the Mathematical Sciences*, which set out the vision and narrative of how the KE infrastructure of mathematical sciences in the UK could be transformed. The review made nine key recommendations, including: *"A national centre in impactful mathematics for the UK should be created to work with industry and government to drive mathematical research through to commercialisation".*

In order to assess the needs of the whole mathematical sciences community an independent consultation paper, *A Knowledge Exchange Connected Centres Network (CCN) for Mathematical Sciences*, was developed to answer this brief. The INI is providing financial and administrative support in the early stages for what has now become known as the *Knowledge Exchange Hub for Mathematical Sciences (KE Hub).*

The *KE Hub* will set out to:

- Massively **scale up** KE activity in the UK, leveraging the experience of the mathematical science national infrastructure.
- **Connect** by drawing together researchers, practitioners, end-users and professionals into Forums which interface with the various activities.
- **Support** existing KE activity in the community whilst growing the network by nurturing untapped pool of researchers, practitioners, and end-users.
- **Deliver** activities through linked projects overseen by a central team.
- **Coordinate** support for mathematical science KE projects from beginning to end.

Through a series of linked projects, the *KE Hub* will facilitate creating a voice for practitioners and end-users, create mobility, create capacity, develop skills, share good practice for low-risk high-reward entry points in KE and broker connections.

A *Knowledge Exchange Manager,* Rachael Harris, was appointed in July 2022 for the development and delivery of the *KE Hub* and the appointment of a scientific lead and development of the governance structure are underway. The *KE Hub* is likely to be formally launched in spring 2023, with pilot activities starting sooner.

A4I - UKRI's Analysis for Innovators Programme

In March 2022, the Gateway was pleased to be appointed as a new Partner in *UKRI's Analysis for Innovators Programme - A4I*. This is a programme that gives UK businesses of any size access to cutting-edge R&D expertise and facilities to help solve problems that they have been unable to tackle using standard technologies and techniques. These could relate to product reliability, cost or product lifetime, but are for an existing product, process or service.

The Gateway took part as an experimental partner organisation in 2019 and helped to make some valuable links between mathematicians and industry within A4I, but no specific funding was available that time to fund projects through the Gateway.

Now, through its established relationships with universities across the UK, within the *A4I* programme, the Gateway is able to connect businesses with the most appropriate mathematical and statistical modellers. Members of the *Gateway Scientific Advisory Panel* or those affiliated with it are working with the Gateway to take forward funded projects.

In addition to providing the contractual hub for specific *A4I* projects with the UK academic mathematical scientists, the Gateway is able to help facilitate other engagement mechanisms to help broker interaction with mathematical science research expertise more widely. This brings additional capability to the *A4I* programme, to provide fundamental mathematical and statistical modelling in addition to existing partners who mainly supply physical testing, and/or computer simulation expertise.

In May 2022, representatives for the Gateway attended 40 brokerage meetings with businesses who had applied to Round 7 of *A4I*. Discussions on potential solutions took place and then a number of these businesses completed applications for funding to work with the Gateway and other *A4I* partners on projects that will be delivered in 2022 – 2023.

The Gateway hopes to be able to collate a number of case studies that illustrate tangible outcomes from mathematical input to these industrial based challenges.

Support of the Mathematical Modelling PhD Student Placements at UKHSA

In October 2021, the *UK Health Security Agency (UKHSA)* sought to hire six PhD students for their Mathematical Modelling PhD student placement scheme. The Gateway, *INI* and the *KTN (Knowledge Transfer Network)* supported the *UKHSA* throughout the recruitment and onboarding process. This scheme was part of the *UKHSA's* Early Career Researcher programme, which aimed to improve organisational capability by bringing in specialist and expert skills to *UKHSA* and served to attract a pipeline of future talent and strengthen organisational links with academia. As well as work experience, the placement also provided the candidates a pastoral and development programme, together with opportunities for technical skills development.

These 3-month internships were open to PhD students with strong mathematics and statistics backgrounds. Working as an intermediary, the *INI* assisted the *UKHSA* to provide Institutional 'buyout' for the students' PhD stipend for the duration of the placement. The candidates were provided with a project within either the *Health Analysis Directorate and Data Directorate* or the *Data Science Directorate*. These are multi-disciplinary analytical directorates of more than 100 individuals each, working at the forefront of the response to *COVID-19*.

Following a successful first round of internships running from January to April 2022, the *UKHSA* are looking to work with the INI and Newton Gateway for a second round of internships to commence in early 2023.

Participation

The Newton Gateway to Mathematics facilitates links between industry, academia and the public sector, ensuring participation from a significant number of researchers in disciplines other than the mathematical sciences.

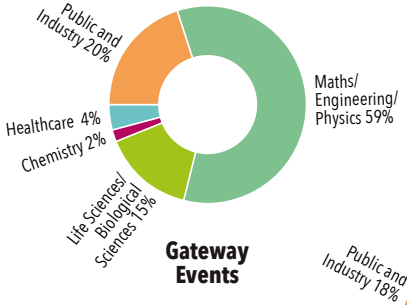
The Gateway continued to engage across a wide range of sectors, with 1,891 delegates attending the twenty-four events that it developed and delivered between August 2021 and July 2022. Due to *COVID-19*, events that took place were delivered predominantly online. Where the event was delivered in person, the Gateway offered the ability for delegates to attend and participate in a hybrid format

The virtual nature of events has enabled an increased diversity of people to attend, including more Early Career Researchers who have engaged in the virtual study groups, as well as an increased number of attendees from oversees who were more easily able to engage.

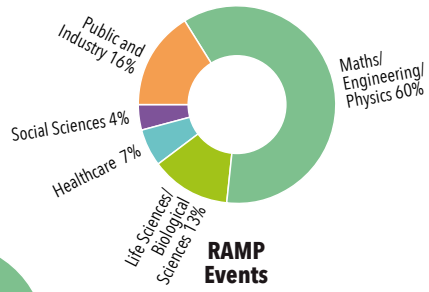
The diversity of sectors the Newton Gateway activities attracted has expanded and includes biotechnology, communication, data analytics and science, epidemiology, energy, engineering, environment, healthcare, information technology, medical imaging, security, space, technology and transport.

Over this year, the events that the Gateway delivered attracted a higher proportion of academic attendees. This is to be expected particularly in relation to the *RAMP* continuity activity as one aim was to ensure engagement with the wider mathematical community and multiple disciplines and sub-fields. These events were attended by delegates from a wide range of academic disciplines, so enabling discussion linked to other relevant fields of research.

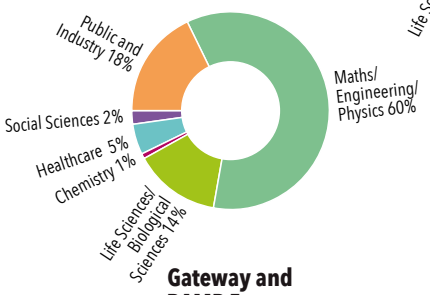
These charts show attendance at Gateway delivered events, divided by affiliation.



Gateway Events



RAMP Events



Gateway and RAMP Events combined

Grants and Funding

The finances for the Newton Gateway are managed by the Isaac Newton Institute. For more information, please refer to the Isaac Newton Institute Annual Report.

The Newton Gateway to Mathematics is an integral component of the Isaac Newton Institute and therefore financial support is provided by *INI* to enable the Gateway to continue to develop and expand its current service to the community. Some events and associated administrative cost are funded via the *INI*'s *UKRI* funding streams.

The *University of Cambridge* has also contributed to the funding of the Newton Gateway to Mathematics through the Higher Education Innovation Funding scheme, which has partially covered administrative costs. Direct costs for specific Gateway activities are funded through partnerships with stakeholders including from industry and the public sector, philanthropy and participant registration fees.

Future Development

The Newton Gateway to Mathematics aims to respond in a speedy and focused way to new ideas and approaches but recognises the need for a targeted and continuous approach to the delivery of longer-term knowledge exchange activities in the mathematical sciences. The series of Thematic Knowledge Exchange Programmes are designed to stimulate and support research activities and include workshops, consultations and project meetings. These include Mathematics of Big Data, Mathematics for Biology and Healthcare Systems, Mathematics for the Environment and Energy, Mathematics for Financial Services, and Mathematics for the Space and Security Sectors.

Activity from September – December 2022

With its ongoing aspiration of playing a key national role in mathematical sciences knowledge exchange, the Newton Gateway to Mathematics has developed the following activities in collaboration with stakeholders, funders and other academic partners.

6th Edwards Symposium – Soft Matter for the 21st Century
(7 – 9 September 2022)

From Dispersive Hydrodynamics to Forecasting, Machine Learning and Back
(24 October 2022)

Liquid Metal Batteries
(15 - 16 November 2022)

Cantab Capital Institute for the Mathematics of Information – Connecting with Industry
(23 November 2022)

Physical Applications of Dispersive Hydrodynamics
(12 December 2022)

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