AMSI WINTERSCHOOL 19

ON COMPUTATIONAL **MODELLING** OF **HETEROGENEOUS** MEDIA

1 – 12 JULY 2019 **QUT**

EVENT REPORT

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Australian Government
Department of Education

QUT

AMSI Winter School 2019 would like to thank the following partners for their support:

AMSI Winter School 2019

On Computational Modelling of Heterogeneous Media

Queensland University of Technology
1–12 July 2019

FOREWORD

The AMSI Winter School is one of five premier flagship events hosted each year around Australia. It forms part of the Securing Australia's Mathematical Workforce: 2016-2020 agreement between AMSI and the Department of Education. Now in its fourteenth year, this key program has become an integral part of the events calendar for PhD and postgraduate students, as well as early-career researchers in the mathematical sciences and cognate disciplines.

Hosted over two weeks, the program offers a range of specialist topics with an overarching theme. The aim of the AMSI Winter School is to develop the next generation of mathematical scientists who can thrive in tomorrow's information age. This program draws upon the knowledge of national and international lecturers at the forefront of their fields, and attracts students from all around Australia.

The complete program, comprising course content and extra activities, is designed to align with the project objectives of the agreement to:

- Strengthen research training and the work-readiness of advanced mathematical sciences graduates
- Promote university-industry collaborations that will encourage the private-sector employment of mathematical sciences graduates
- Attract and improve the retention of senior undergraduate students in the mathematical sciences, with particular attention to women and Aboriginal and Torres Strait Islander students

AMSI Winter School 2019 was jointly funded by the Australian Mathematical Sciences Institute (AMSI) and the Australian Government's Department of Education, with support from Queensland University of Technology, the University of Queensland, the Australian Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS), the Queensland Cyber Infrastructure Foundation (QCIF), and the BHP Foundation through the Choose Maths program.

DIRECTOR'S REPORT

Professor Ian Turner, AMSI Winter School 2019 Event Director

The 2019 AMSI Winter School on Computational Modelling of Heterogeneous Media was held on the QUT Gardens Point Campus from Monday July 1st to Friday July 12th in the world-class facilities available in the Science and Engineering Centre. There were 74 people from across the nation who participated in the two-week program, which included 35 PhD students, two honours students, two masters students, one undergraduate student, 14 early-career researchers, nine academics and one retiree. There were also seven international participants from China comprised of two academics and two PhD students from Jimei University, as well as three occupational trainee visiting PhD students currently studying at QUT. Three researchers from Boeing Defence Australia also attended. The participants from outside of Brisbane either stayed at the ATIRA Southbank accommodation, which is a short walk over the Goodwill Bridge to QUT, or close to the Gardens Point campus in the city. Our colleagues in the School of Chemistry, Physics and Mechanical Engineering at QUT strongly supported the Winter School by sponsoring nine of their PhD students to attend.

The Winter School program was scheduled over two weeks across three main lecture streams in fractional calculus, Stokes flow and Krylov subspace methods and multiscale modelling. In Week One, Professor Liu presented lectures on the fundamentals of fractional calculus, Dr Carr presented lectures on computational homogenisation and Dr Pestana gave introductory lectures on the application of the finite element method for Stokes flow. During Week Two, Dr Yang presented lectures that summarised the numerical methods used to solve space-fractional reaction-diffusion equations and Dr Pestana continued her lectures on numerical methods for Stokes Flow focusing on the linear algebra aspects of the underlying solvers. Professors Roberts and Peterseim presented sub-themes in multiscale modelling. All the lecture content was very well received by the participants. They remarked on the high quality of the lecture material and the extensive knowledge of the lecturers.

As the event director, I thoroughly enjoyed the opportunity to organise and host the 2019 AMSI Winter School at QUT. I sincerely thank and acknowledge the efforts of our QUT administrative staff who made this such a successful event. The team included the School of Mathematical Sciences professional staff, Amanda Kolovrat and Michelle Spanton, together with the Science and Engineering Faculty (SEF) Engagement and Communication teams who assisted with the coordination of events and marketing of the Winter School program across QUT and more broadly through the various external networks linked to SEF. Thanks also to the local scientific academic committee through Professors Tim Moroney and Fawang Liu who assisted with the design of the Winter School academic program and Professor Fawang Liu and Drs Elliot Carr and Qianqian Yang for delivering their well-received short courses. Also, thanks to Professor Kevin Burrage at QUT who helped with the identification of the international lecturers. I particularly acknowledge Andree McFarlane for overseeing the entire event organisation, which made this a special occasion for QUT. I also wish to thank the AMSI staff members Anna Muscara (Project Coordinator, Research & Higher Education) and Chloe Pearse (National Program Manager, Research & Higher Education) who worked alongside us throughout all stages of the planning and running of the Winter School. It was a true partnership and they were a delight to deal with. I also acknowledge the strong support offered by the Head of School of Mathematical Sciences, Professor Troy Farrell, in hosting the event at QUT. Finally, to the Winter School lecturers and participants, I thank you for making the Winter School such a memorable success. It was my absolute pleasure to host you at QUT during the event and I hope we all find the opportunity to meet again in the future.

Professor Ian Turner, 2019 AMSI Winter School Event Director

COURSE PROGRAM

PROGRAM THEMES:

Computational Homogenisation
Finite Volume Methods
Fractional Calculus
Krylov Subspace Methods
Multiscale Modelling
Stokes Flow

Course 1:

Fractional Calculus

Professor Fawang Liu, Queensland University of Technology, Australia

Course 2:

Computational Homogenisation of Complex Heterogeneous Media

Dr Elliot Carr, Queensland University of Technology, Australia

Course 3:

Numerical Methods for Stokes Flow

Dr Jennifer Pestana, University of Strathclyde, Glasgow

Course 4:

Numerical Methods for Solving Space-Fractional Reaction-Diffusion Equations

Dr Qianqian Yan, Queensland University of Technology, Australia

Course 5:

Numerical Homogenisation and Beyond

Professor Dr Daniel Peterseim, The University of Augsberg, Germany

Course 6:

Multiscale Modelling of Microscale Heterogeneous Systems

Professor Tony Roberts, The University of Adelaide, Australia

Fractional Calculus

Professor Fawang Liu, Queensland University of Technology

Lecture 1: A brief introduction to fractional calculus with applications

Topics Include:

1. A brief introduction to fractional calculus with applications
2. Fractional integrals and derivatives
3. Stability and convergence analysis of finite difference methods for the space fractional diffusion equations (SFDEs)
4. Fractional method of lines for the space fractional advection-diffusion equations (SFADEs)
5. Fractional finite volume methods (FVM) for the SFDEs with variable coefficient (SFPDE-VC)
6. An unstructured mesh FVM for the 2D-SFDE-VC

Lecture 2: Numerical methods, convergence and stability analysis for the time, time-space fractional partial differential equations

Topics include:

1. Finite difference methods for the time FDEs
2. Finite difference methods for the anomalous sub-diffusion models (ASub-DM)
3. Finite difference methods for variable-order ASub-DM
4. Novel high-order space-time spectral methods for the time-fractional Fokker-Planck equations
5. Meshless methods for the fractional partial differential equations

Lecture 3: Numerical methods for the time-space, space fractional partial differential equations with applications

Topics include:

1. Anomalous diffusion in human brain tissue (finite difference methods, stability and convergence analysis for 2D space-time fractional Bloch-Torrey equations)
2. Diffusive processes in heterogeneous media and applications in cardiac science (a Crank-Nicolson alternating direction implicit Legendre spectral method, stability and convergence analysis for the 2D Riesz space fractional nonlinear reaction-diffusion model)
3. Fractional dynamical systems and applications, such as MRI to probe tissue microstructure, non-Newtonian fluids, computational finance, signal filtering (unstructured mesh finite element methods for fractional dynamical systems in irregular domains)

Lecture 4: Parameters estimation techniques of complex fractional dynamic systems and analytical solutions for the multi-term time-space fractional partial differential equations

Topics include:

1. Parameter estimation for a phenomenological model of the cardiac action potential
2. Parameter estimation for dynamical models in biological systems
3. Parameter estimation techniques for fractional dynamical epidemic models of dengue fever
4. Parameter estimation techniques the dynamic system of anomalous relaxation of human brain tissue
5. Analytical solutions for the multi-term time-space fractional partial differential equations

---

"[Professor Fawang Liu's] *level of knowledge was immense"*

Chantelle Blachut, The University of Queensland

"Fractional calculation lectures gave us a new direction to solve the differential equation."

Kajal Gujarati, Murdoch University

Computational Homogenisation of Complex Heterogeneous Media

Dr Elliot Carr, Queensland University of Technology

Many scientific and engineering problems involve heterogeneous media, where material properties (e.g. permeability, conductivity, diffusivity) vary spatially. Practical applications include groundwater flow in aquifers, heat and mass transport during drying processes and diffusion of molecules in biological tissues, to name a few. For problems where the material properties vary at a small scale, solving the governing mathematical model is prohibitively expensive since a very fine mesh/grid is required to capture the heterogeneous detail. Broadly speaking, homogenisation refers to the process of upscaling the fine-scale description of the flow/transport to a coarser-scale, thus enabling computationally feasible simulations. This process essentially involves homogenising part of the domain (or the full-domain) by replacing the spatially-varying material properties with averaged or effective properties.

This course focuses on modelling and simulating continuum diffusion in complex two-dimensional heterogeneous media. We will see how homogenising a heterogeneous domain and computing its effective diffusivity involves solving a suitable partial differential equation over the domain with appropriate boundary conditions. Apart from some simple cases, analytical solutions to such problems are unavailable. Instead, numerical solutions will be developed using finite volume discretisation and implemented in MATLAB.

"Dr Elliot Carr was amazing. I really enjoyed the way he lectured."

Fatemeh Ansarizadeh, Swinburne University

"I enjoyed Dr Elliot Carr's lectures and MATLAB lab. He is a fantastic teacher to explain mathematics in an easy way."

Kajal Gujarati, Murdoch University

Numerical Methods for Stokes Flow

Dr Jennifer Pestana, The University of Strathclyde, Glasgow

Stokes flow arises in many applications, including modelling ice sheets, lava and polymers. This type of viscous flow is described by the Stokes equations, which couple together the fluid's velocity and pressure. Often, fine resolution solutions of the Stokes equations are required in applications, the computation of which requires sophisticated numerical methods.

This course will discuss how to efficiently solve Stokes problems from start to finish. We will look at the wellposedness of these equations and their discretisation by a Galerkin finite element method. A key component of finite element (and other) discretisations is the solution of a system of equations with a large, sparse coefficient matrix. These linear systems are typically solved by preconditioned Krylov subspace methods, a family of iterative methods that exploit sparsity.

The techniques learnt here can be applied to other differential equations, and other linear systems of equations.

COURSE OUTLINE

1. Stokes flow: motivation and inf-sup conditions

We will introduce and motivate the Stokes equations before deriving the weak form. This will enable us to relate the Stokes equations to a constrained optimisation problem that leads naturally to the inf-sup condition for well-posedness of Stokes problems.

2. The finite element method for Stokes problems

We will start by deriving the finite element method for a Poisson problem, before developing mixed finite element methods for the Stokes equations. A key issue, on which we will focus, is understanding when a discrete inf-sup condition holds.

3. Iterative methods for the Stokes equations

To obtain the finite element solution to the Stokes equations we must solve a linear system. The final part of this course investigates how to do this using Krylov subspace methods. We will use the MINRES method, and will look at how to accelerate its convergence rate by preconditioning.

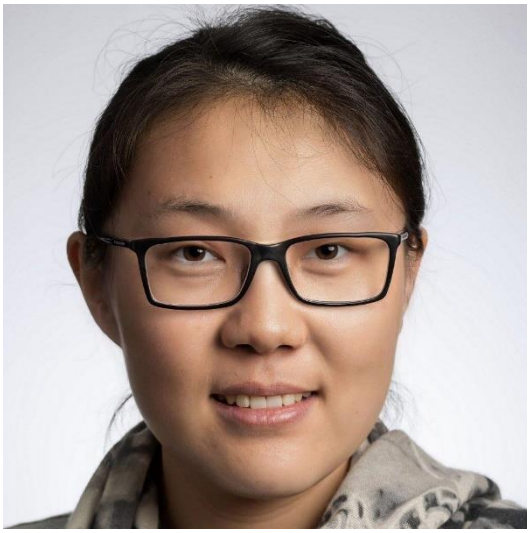
"Dr Jen Pestana's lectures were incredible. Everything was clear, well explained and very interesting."

Chantelle Blachut, The University of Queensland

Numerical Methods for Solving Space-Fractional Reaction-Diffusion Equations

Dr Qianqian Yang, Queensland University of Technology

Course Outline



Fractional differential equations have been increasingly used as a powerful tool to model the non-locality and spatial heterogeneity inherent in many real-world problems. The booming popularity of fractional models has stimulated demand for efficient solution techniques which can provide rapid insight and visualisation into solution behaviours. It is well-known that analytical solutions are available only for some special, simple (usually linear) fractional models. To solve more general fractional models (either linear or nonlinear), numerical solution techniques are preferred.

A constant challenge faced by researchers in this area is the high computational expense of obtaining numerical solutions to fractional differential equations, owing to the non-local nature of fractional derivatives. The search for high-efficiency numerical methods that can significantly reduce the amount of computational time has become a new trend in the literature.

Preconditioning and Krylov subspace techniques have been a common theme in this context, with authors seeking to reduce the cost of solving the (typically dense) linear systems or matrix function equations that arise from spatial discretisations of fractional differential equations.

In these lectures, we will learn together how to solve space-fractional reaction-diffusion equations using an efficiently preconditioned Lanczos method.

"I really enjoyed the course content and this was the most enjoyable aspect for me. Although some material was a bit of a struggle for me to follow, all the lecturers felt passionate about the material they were presenting and I gained a lot of knowledge in a way I don't think I would have just reading through the equivalent material myself."

Brodie Lawson, Queensland University of Technology

Numerical Homogenisation and Beyond

Professor Dr Daniel Peterseim, University of Augsberg, Germany

Course Outline

Many physical processes in micro-heterogeneous media such as modern composite and functional materials are described by partial differential equations with coefficients that represent complicated material microstructures. The coefficients are often the result of measurements combined with inverse modelling and, hence, underlie errors and uncertainty. Given the complexity of these processes, the key to efficiently and reliably simulate some relevant classes of such problems involves the construction of appropriate macroscopic computational models with significantly reduced oscillations and randomness. Homogenisation is a multiscale method for the derivation of such effective models and this series of lectures aims to promote the recent methodological progress in this context.

This series of lectures will start with a brief survey of constructive approaches in the mathematical theory of deterministic and stochastic homogenisation, their quantitative analysis under the usual periodicity, ergodicity and scale-separation assumptions. The main part will then be on novel computational approaches based on subspace decomposition that remain valid beyond such strong structural assumptions. In the end, we will bridge the analytical and computational approaches to homogenisation and illustrate some surprising connections to seemingly unrelated areas such as the theory of iterative solvers and domain decomposition, multiresolution analysis, classical stabilisation techniques in the theory of finite elements, principal component analysis and information games.

"I would also like to especially acknowledge the lectures by Prof. Daniel Peterseim and Dr Jen Pestana, who both delivered excellent lectures."

Christopher From, Queensland University of Technology

Multiscale Modelling of Microscale Heterogeneous Systems

Professor Tony Roberts, The University of Adelaide

Course Outline

1. Overview of macroscale modelling. Homogenise period-two diffusion on a lattice—the leading approximation. Resolve the microscale to regularise, rather than "singularise". Boundary conditions. An ensemble of phase shifts underpins rigorous homogenisation, and underpins construction of higher-order corrections. Nonlinear pattern formation is similarly rigorously supported. Open problems.
2. Macroscale computation of microscale systems. "One Patch to rule them all, …" Automatic macroscale closure. Nonlinear diffusion in one patch. A simple atomic simulation. Classic interpolation couples patches consistently and with dynamical systems support. Patch functions of the equation-free toolbox.
3. Macroscale computation of microscale spatial complexity. Couple patches of microscale heterogeneous diffusion for macroscale accuracy. How do communication delays affect such simulations? Open problems.
4. Projective integration computes only on small bursts of time. Accuracy and stability for such schemes, even integrating backward in time with forward-time simulation. Projective integration of the equation-free toolbox. Open problems.
5. Possible workshop: using the equation-free toolbox, developing the toolbox.

"I think the most valuable thing in the school was that the lecturers took the time to inform us all of open problems in their fields.

As most of the attendants are PhD students, or young post-docs, this sort of opportunity is fantastic!... Some of these opportunities can't be found anywhere else."

Abhishek Bhardwaj, Australian National University

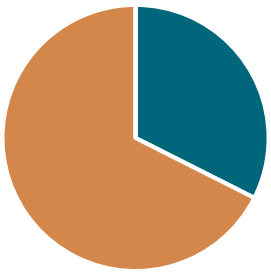
PARTICIPATION BREAKDOWN

UNIVERSITY/INSTITUTION	
ACEMS	4
Australian National University	4
Curtin University	1
Deakin University	1
Flinders University	1
Monash University	1
Murdoch University	2
Griffith University	1
Jemei University, China	4
Boeing Defence Australia	3
Queensland University of Technology	40
Swinburne University of Technology	2
The University of Newcastle	2
The University of Queensland	4
The University of Sydney	1
The University of Wollongong	1
Other	2
TOTAL	74

"Having the opportunity to connect with specialists in different areas of mathematics and to see how my research as an engineer is interlinked to their work. Furthermore, the Diversity in STEM panel was very relevant to me and made me feel included and supported."

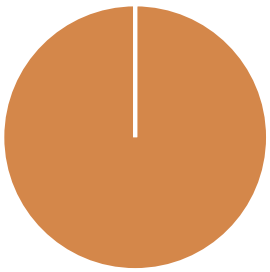
Anonymous

Gender



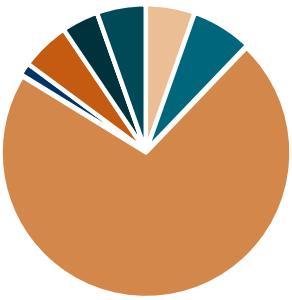
Gender	Number	%
Male	50	68%
Female	24	32%

ATSI Status



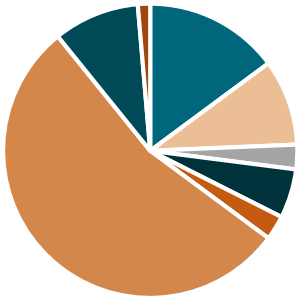
ATSI Status	Number	%
Yes	0	0%
No	74	100%

State/Territory



State/Territory	Number	%
ACT	4	5%
NSW	5	7%
QLD	53	73%
NT	0	0%
SA	1	1%
TAS	0	0%
VIC	4	5%
WA	3	4%
International	4	5%

Academic Status



Academic Status	Number	%
Undergraduate	1	1%
Honours	2	3%
Masters	2	3%
PhD	40	54%
Academic	11	15%
Early-Career/Post Doc Researcher	14	19%
Industry/Other	4	5%

Residency Status

Academic Status	Number	%
Australian Citizen	39	53%
Permanent Resident	6	8%
Student Visa	18	24%
Other	11	15%

"The topics of the Winter School lectures were very interesting. It presented a lot of possible avenues of research to explore for my future research. I also met quite a number of people who are working in similar areas… The social events were a nice avenue to network and have conversations with the other participants in a more 'relaxed setting', and they were all very nice."

Anonymous

GRANTS

AMSI TRAVEL GRANTS

AMSI Travel Grants are funded by AMSI, the Australian Department of Education and Training, and Queensland University of Technology. These grants allow students to travel interstate and from rural areas to attend the Winter School program. They offer both travel and accommodation support to students who would otherwise be unable to attend the event, and are awarded on a competitive basis. In 2019, AMSI Travel Grants were awarded to the following 11 Winter School participants:

Liam Anderson, Swinburne University of Technology
Joshua Mercurio, Flinders University
Hanz Martin Cheng, Monash University
Balaje Kalyanaraman, The University of Newcastle
Michael Groom, The University of Sydney
Bashiruddin Nabubie, Curtin University
Matthew Berry, The University of Wollongong
Shilu Feng, The Australian National University
Abhishek Bhardwaj, The Australian National University
Lishan Fang, The Australian National University
Michael Robertson, The Australian National University

"I really appreciated the thought and planning that went into creating a thoroughly enjoyable experience over the entire two weeks. The courses were all super interesting and linked well with each other and the program extras were really valuable for helping to connect with the other attendees and organisers."

Michael Groom, The University of Sydney

CHOOSE MATHS GRANTS

Choose Maths Grants are designed to encourage female participants from the mathematical sciences and cognate disciplines to attend AMSI Flagship events. These grants offer travel, accommodation and carer support to those travelling from rural areas and interstate. Funded by AMSI and the BHP Foundation (out of the Choose Maths initiative), the following five students were awarded support to attend the 2019 Winter School program:

Fatemeh Ansarizadeh, Swinburne University of Technology
Riya Aggarwal, The University of Newcastle
Sara Vahaji, Deakin University
Kajal Gujarati, Murdoch University
Jyothi Jose, Murdoch University

"I could secure excellent accommodation due to Choose Maths grant funding. Much appreciate great hospitality from all staff members of QUT… From [the] Winter School program, a few career opportunities have opened as I know the new people in the field of fluid dynamics. It's great to know how mathematics society works in Australia."

Kajal Gujarati, Murdoch University

PROGRAM EXTRAS

Opening Ceremony

The Winter School program officially commenced with the opening ceremony, which was hosted by QUT on Monday 1 July in the Gardens Theatre X-block Gardens Point Campus. AMSI Winter School participants, guest lecturers and distinguished guests were welcomed to Brisbane and the QUT Gardens Point Campus by the Winter School Director Professor Ian Turner.

We were very fortunate to have the Vice Chancellor and President of QUT Professor Margaret Sheil AO as our keynote speaker for the opening ceremony. Professor Sheil welcomed the AMSI Winter School participants and gave an excellent overview of the importance of the mathematical sciences discipline and the opportunities studying in this field will offer our participants in their future careers. Professor Sheil reflected on the strong support for the mathematical sciences both nationally and at QUT. She applauded the efforts of AMSI with their mission to champion the mathematical sciences for Australia's advancement.

Distinguished guests at the event included Professor Tim Brown (AMSI Director), Professor Gordon Wyeth (Executive Dean, Faculty of Science and Engineering, QUT), Professor Troy Farrell (Head of School of Mathematical Sciences, Science and Engineering Faculty, QUT), Professor YuanTong Gu (Acting Head of School of Chemistry, Physics and Mechanical Engineering, QUT), Professor David Lovell (Head of School of Electrical Engineering and Computer Science, QUT), Professor Stephen Wright (University of Wisconsin and Adjunct Professor QUT) and Dr Phillip Isaac representing the School of Mathematics and Physics from The University of Queensland.

The opening ceremony concluded with light refreshments. Participants were also invited to attend a campus tour to get acquainted with the QUT Garden Point Campus facilities and prior to lunch they also attended the AMSI APR Intern presentation given by Adam Lenihan from AMSI, who is the business development officer and oversees the APR.Intern program. Adam informed the audience of the many great opportunities the program offers and encouraged them to consider getting involved in the future.

Special Lecture

Participants were invited to attend a special lecture given by Professor Michael Stumpf from the University of Melbourne who holds the position of Professor for Theoretical Systems Biology, Melbourne Integrative Genomics, in the School of Biosciences & School of Mathematics and Statistics. He is also a visiting professor at Imperial College London, UK. This lecture was held in Z-Block on the QUT campus and members of the mathematics community including mathematicians and statisticians from QUT, ACEMS and The University of Queensland also took advantage of the opportunity to attend. Afternoon tea was provided prior to the lecture.

Professor Stumpf spoke on largescale robustness analysis and the elusive ubiquity of Turing pattern mechanisms. This special lecture was jointly sponsored by ACEMS and AMSI. Professor Stumpf covered a wide cross section of topics during his very interesting and fascinating lecture. He informed us that Turing patterns underlie many

fundamental developmental processes but operate over narrow parameter ranges, raising the conundrum of how evolution can ever discover them. The audience was thoroughly engaged with the topic and asked a number of questions following the lecture. We then thanked Professor Stumpf for his excellent talk and acknowledged his involvement with the Winter School program.

Diversity in STEM

This year for the first time, the AMSI Winter School hosted an event to celebrate diversity in STEM as part of the two-week conference. The event entitled "A Celebration of Mathematics: Diversity in STEM" was held at Gardens Theatre Foyer, X-Block, QUT Gardens Point campus. It was proudly sponsored by the AMSI CHOOSE Maths Program and the Science and Engineering Faculty at QUT.

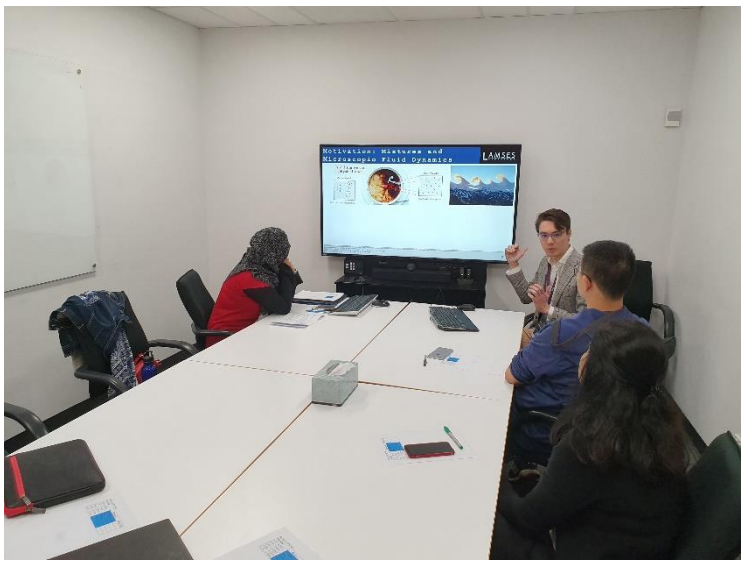
Four panel members were invited to talk about their career experiences and studies in the STEM area.

- Grace Garden, Researcher (Mathematics), Boeing Research and Technology, Australia
- Taylah Griffin, Test Engineer, Wedgetail Team, Boeing Defence, Australia
- Dr Jennifer Pestana, Lecturer, Department of Mathematics and Statistics, University of Strathclyde, Glasgow
- Dr Qianqian Yang, ARCE ECRA Research Fellow, School of Mathematical Sciences, QUT

The MC for the night was Deryn Vahl Meyer, SEF Associate Dean, International, Engagement and Diversity at QUT. Julia Collins from AMSI also addressed the audience on the AMSI Choose Maths project and the positive long-term impacts on encouraging more diversity in the mathematical sciences.

Over 70 guests were in attendance to learn about the mathematical journeys of the panel and then participated further in networking opportunities and discussion over light refreshments. This was a great night of celebration and we received some excellent feedback on the wonderfully diverse set of careers of our speakers. The audience also had the opportunity to engage in a lively Q&A discussion with the panel that delved more closely into their career experiences and the panel also shared tips on how to encourage more diversity within the mathematical sciences in future generations. We were very thankful to the speakers for sharing their career journeys with us on the night.

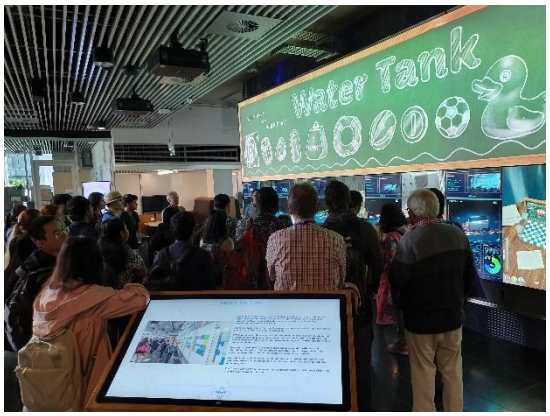
Participant Talks



The participant talks provide an opportunity for students to share their research with their peers and to see the broad scope of study for mathematics in their general field. All attendees were asked to give a 15-minute presentation on either their thesis research project or another topic of specialisation, with an added five minutes to field any questions from the audience. These talks were held on Thursday morning of Week One. The participants were first separated into eight groups where a total of 43 talks were delivered. Participants were then asked to vote for the best presentations in their respective group session. The eight group winners were then invited to present their talks to the entire Winter School cohort. Congratulations to Abhishek Bhardwaj (ANU) who was voted as the best participant speaker. Chantelle Blachut (UQ) and Brodie Lawson (QUT) also received honourable mentions for their presentations by tying for second place overall. Liam Anderson (Swinburne), Michael Groom (The University of Sydney), Riya Aggarwal (UON), Chris From (QUT) and Balaje Kalyanaraman (UON) were also nominated as shortlisted finalists. Congratulations to all of the participants for their very well-prepared presentations.

Robotics Vision Tour and Cube Visit

On Friday morning of the first week, the Winter School participants were invited to visit two areas of research strength at QUT. The first was the Australian Centre for Robotic Vision. This tour allowed the cohort to experience first-hand some of the excellent research being conducted to realise a mission of developing new robotic vision technologies expanding the capabilities of robots. The group was split into two and volunteers from the centre took us through the facility to explain how the current research technology is being applied in industry.



The second tour was to the QUT CUBE located in P-Block of the Science and Engineering Centre. The Cube is the world's largest digital interactive learning display. The Winter School participants were given a behind-the-scenes tour of the facility and were given a chance to examine the full functionality of the display interactively. They even put on a visualisation show especially for us.

Friday Night Social

The Winter School cohort, lecturers and organisers attended the Friday Night Social at the end of the first week. This was an informal opportunity for students and lecturers to socialise over gourmet burgers and fish and chips at the Southbeach Social, located on the beach at Brisbane's popular Southbank. It was a good chance for everyone to relax with peers, lecturers and Winter School organisers in a fun atmosphere and this was an excellent opportunity for the cohort to mix and mingle and get to know each other better outside of lectures.

Public Lecture

The 2019 Winter School Public Lecture was held on Monday 8 July in the Kindler Theatre at the Queensland University of Technology, Science and Engineering Centre. This event was an occasion for members of the public to interact with the mathematical sciences community and be exposed to the broad range of applications and positive impacts that mathematics has on everyday life.

The public lecture was presented by three members of Boeing Defence Australia: Michael Elford, Dr Andrew Stephan and Dr Yunpeng Zhang. They spoke at length on numerical simulation in sheet metal manufacturing processes and its impact on the aerospace industries.

The speakers explored two different numerical schemes for simulating sheet-forming manufacturing processes and explained the approach to modelling the material behaviour. They also discussed the importance of computational modelling in the wider aerospace industries and highlighted the outcome of a recent collaboration between Boeing and UQ researchers that led to a novel approach to speed up simulations considerably by using gaming computer graphics cards and mathematics. Audience members had the opportunity to see visualisations of results, methods for model validation, and get a sneak peek at the day-to-day lives of mathematicians working in this exciting field. The audience also received some insight into opportunities for graduates and interns wanting to pursue a career in this profession. Over 60 people attended and time was given for questions and discussion, followed by supper.

Conference Dinner

On Thursday July 11th, the entire cohort of participants, lecturers, Winter School organisers, sponsors and special guests were invited to a formal sit-down dinner at Old Government House located within the Gardens Point Campus at QUT. The ambience was excellent and the Winter School participants enjoyed each other's company as well as the great opportunity to discuss with the organisers, our industry sponsors, the QUT Head of School of Mathematical Sciences and other distinguished guests.

Pre-dinner drinks were served in the dining room from 7pm and guests were seated by 7.30pm.

Winter School Director Professor Ian Turner welcomed everyone to the conference dinner and gave a brief highlights summary of the event, outlining the accomplishments of the previous two weeks. He acknowledged the high quality of the lectures and thanked all of the academics involved for preparing such well-received short courses. Professor Turner then introduced Chloe Pearse (AMSI Program Manager, Research and Higher Education), who spoke about the AMSI Higher Education program and other opportunities for the participants within AMSI before introducing Professor Joe Grotowski from The University of Queensland. Professor Grotowski spoke about the AMSI Winter School 2020 theme of Representation Theory and was able to inform this year's cohort that the upcoming Winter School will be in partnership with MSRI and will include 20 international PhD students from MSRI member institutions in North America. We encouraged all of our participants to consider attending this exciting event to be hosted at The University of Queensland in 2020.

After dinner our guest speaker was Professor Troy Farrell (Head of School Mathematical Sciences, QUT), who gave an excellent talk on mathematics and the opportunities it brings.

Professor Turner and Chloe Pearse then presented the award for the best participant talk whilst acknowledging the other finalists.

The dinner finished around 10pm with many guests continuing their discussions on afterwards at Southbank.

"Very well organised events. Thanks to the AMSI organisers for putting so much effort to hold all types of events on top of lectures. The very broad topics of those events connected between industry interests and academic projects get us to know the potential use and impact of our knowledge and skills.

Super helpful for career development not only in a sense that the knowledge and techniques learnt in the school would directly help my research but also the connections have been established between my peers across the whole country."

Shilu Feng, Australian National University

"Thanks for connecting industry people with the school. I really enjoyed that part of the school. Plus I learned how to reach them in the future."

Riya Aggarwal, The University of Newcastle

FEEDBACK ANALYSIS

Fifty-one per cent of attendees of the 2019 Winter School completed the post-event feedback survey. Once again, the data illustrates the importance of this flagship event in assisting students to collaborate with peers and extend their knowledge by providing them with access to the world leaders in their chosen field. The opportunities to link in and network with industry have also proved to be invaluable experiences as attendees embark on their professional careers. This data points to both immediate benefits as well as potential ongoing benefits in the long term for both innovation and career development. In rating their overall experience, with 1 being poor and 10 being excellent, participants rated the event an average of 9.2.

Of those who completed the survey, 50 per cent of students stated that they attended Winter School because the theme was related to their overall research interests, and an additional 45 per cent indicated that their main motivation for attending was to broaden their knowledge base. A further 2.5 per cent noted that they had attended to help their career prospects, or to network. This data suggests that students attending this event are future-focused and keen to pursue the mathematical sciences in the long term. It also suggests that there is an appetite to deepen their already expert knowledge and learn from the most eminent minds leading the world on their chosen topics.

There was positive feedback among attendees who reported that they came away from the program with a wider skill set that could be applied to their everyday mathematical activities (45 per cent agreed; 42 per cent strongly agreed), including the strengthening of their ability to conduct individual research outside of the program (45 per cent strongly agreed; 45 per cent agreed).

The data also revealed the program's importance in giving attendees an opportunity to network and form friendships and professional relationships with others in their cohort (in an environment that can otherwise be isolating). Forty-five percent strongly agreed that they had made useful contacts with whom they would potentially collaborate, and an additional 29 per cent agreed with this statement.

Attendees found the Winter School program informative and useful. Most felt that the course had strengthened their mathematics credentials (55 per cent strongly agreed; 39 per cent agreed), and that it had exposed them to other research fields that they may not have otherwise known about (66 per cent strongly agreed; 21 per cent agreed). All students completing the feedback survey unanimously said that they would recommend AMSI Winter School to their friends and colleagues.

"I found it to be incredibly informative and inspiring… I became friends with a group of talented academics and also established some industry contacts… The whole event was really well coordinated."

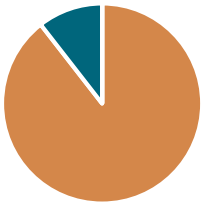
Amar Velic, Queensland University of Technology

"It was a great opportunity for me to expand my knowledge in porous media flow as well as modelling… I could adapt some knowledge about how I can do my PhD in a different perspective."

Jyothi Jose, Murdoch University

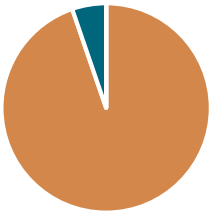
OVERALL, THE SCHOOL WAS OF A HIGH STANDARD

Strongly Agree	89%
Agree	11%
Neutral	0%
Disagree	0%
Strongly Disagree	0%



OVERALL, THE SCHOOL WAS WELL-ORGANISED

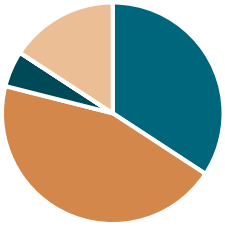
Strongly Agree	95%
Agree	5%
Neutral	0%
Disagree	0%
Strongly Disagree	0%



THE DIVERSITY IN STEM EVENT WAS AN INCLUSIVE AND EDUCATIONAL EXPERIENCE

Strongly Agree	60%
Agree	16%
Neutral	8%
Disagree	0%
Strongly Disagree	0%
Not Applicable	16%

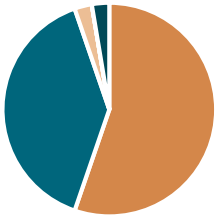
THE PUBLIC LECTURE WAS INTERESTING AND INFORMATIVE



Strongly Agree	34%
Agree	45%
Neutral	5%
Disagree	0%
Strongly Disagree	0%
Not Applicable	16%

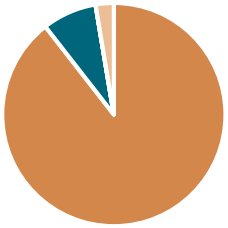
THE SCHOOL STRENGTHENED MY MATHEMATICAL CREDENTIALS

Strongly Agree	55%
Agree	39%
Neutral	3%
Disagree	0%
Strongly Disagree	0%
Not Applicable	3%



I WOULD RECOMMEND THE WINTER SCHOOL TO OTHERS

Strongly Agree	89%
Agree	8%
Neutral	0%
Disagree	0%
Strongly Disagree	0%
Not Applicable	3%



"[I enjoyed] the excellent range of topics in the lectures that allowed me to expand my knowledge on a wide range of topics because they are not something I have been able to experience elsewhere."

Megan Farquhar, Queensland University of Technology

STUDENT PROFILES

Enabling a mother to network with academia and industry at AMSI Winter School 2019

Choose Maths Grant recipient Sara Vahaji (Deakin University)

Being both a parent and a lecturer in mechanical engineering, Sara Vahaji appreciates the value of her Choose Maths Grant enabling her participation at AMSI Winter School, stating that without this support her attendance would not have been possible.

"I am especially grateful for the childcare (component of the grant) … as I have young twins who had to be taken care of while I attended the sessions. I couldn't have attended the program if I didn't receive this support."

Sara's research centres upon numerical investigations of multiphase flows using finite volume methods, or as she simply puts it: "I simulate, study and predict the flow behaviour in different conditions." Investigations led by Sara are enabling a better understanding of the underlying physics of systems involved with fluids for the purpose of improving the efficiency of such systems. "My model could be used for many applications including subcooled boiling, nasal drug delivery and bubbly flow around submerged objects."

As a Choose Maths Grant recipient, Sara identified networking opportunities and practical training sessions as the most valuable elements of her participation in AMSI Winter School.

"In my opinion, such initiatives are invaluable. The Choose Maths Grants provide opportunities for women in STEM to attend programs like AMSI Winter School where they could network with people in academia and industry at different levels."

"Also, the training that is offered in such programs enhances the knowledge of women in mathematics that would eventually help the presentation of women in STEM and balance the gender equity in maths-related fields," Sara adds. "I am going to apply some of the new approaches that I have learnt during the program on my model."

Choose Maths Grants are part of a broader program being delivered by AMSI Schools with support from the BHP Foundation to increase participation of women across the discipline—an ambition that Sara Vahaji both personifies and endorses. "I believe the initiatives that AMSI Schools and BHP Foundation are taking to support women in maths are invaluable and helpful."

EVENT COMMITTEES

AMSI would like to acknowledge and thank all the individuals who contributed their time and expertise to making Winter School 2019 a resounding success:

STANDING COMMITTEE

Professor Ian Turner (Chair and Event Director)—Queensland University of Technology

Troy Farrell—Queensland University of Technology

Joseph Grotowski—The University of Queensland

Phillip Isaac—The University of Queensland

Tim Brown—Australian Mathematical Sciences Institute

Mat Simpson—Queensland University of Technology

Chloe Pearse—Australian Mathematical Sciences Institute

Andree McFarlane—Queensland University of Technology

Anna Muscara (Committee Secretary)—Australian Mathematical Sciences Institute

EVENT ORGANISING COMMITTEE

Ian Turner (Event Director)—Queensland University of Technology

Troy Farrell—Queensland University of Technology

Andree McFarlane—Queensland University of Technology

Amanda Kolovrat—Queensland University of Technology

Chloe Pearse—Australian Mathematical Sciences Institute

Anna Muscara—Australian Mathematical Sciences Institute

"The whole series of extra events were very enjoyable. AMSI Winter School is not only a place to learn maths, but it's more about knowing what maths could do. In this sense, all the extra events helped to achieve the goal… The effort and time that Ian, Andree and Anna and all other AMSI Winter School organisers have put in to host the events was tremendous. The entire 2 weeks program ran so smoothly, made me feel like studying at home."

Shilu Feng, Australian National University

AMSI WINTERSCHOOL 19

ON COMPUTATIONAL MODELLING OF HETEROGENEOUS MEDIA

1 – 12 JULY 2019 QUT

THEMES INCLUDE

COMPUTATIONAL HOMOGENISATION
FINITE VOLUME METHODS
FRACTIONAL CALCULUS
KRYLOV SUBSPACE METHODS
MULTISCALE MODELLING
STOKES FLOW

LOCAL AND INTERNATIONAL EXPERT SPEAKERS

REGISTER WS.AMSI.ORG.AU

AMSI Australian Mathematical Sciences Institute
Australian Government Department of Education and Training
QUT
ACEMS
BHP Foundation

AMSI RESEARCH

Australian Mathematical Sciences Institute

Research and Higher Education
Building 161 C/- The University of Melbourne
VIC 3010 Australia

events@amsi.org.au
www.amsi.org.au

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE