EXECUTIVE SUMMARY

This report covers our activities from June 14, 2025 through June 13, 2025 (which we refer to as the reporting period). This report includes the 2024 summer research programs (RIPS and GRIPS). The 2025 summer programs are underway at the time of reporting and will be included in the next annual report.

IPAM held two long programs in the reporting period:

- Mathematics of Intelligences (September 19 - December 13, 2024)
  - Mathematics of Intelligences Opening Day (September 9, 2024)
  - Mathematics of Intelligences Tutorials (September 10-13, 2024)
  - Workshop I: Analyzing High-dimensional Traces of Intelligent Behavior (September 23-27, 2024)
  - Workshop II: Theory and Practice of Deep Learning (October 14-18, 2024)
  - Workshop III: Naturalistic Approaches to Artificial Intelligence (November 4-8, 2024)
  - Workshop IV: Modeling Multi-Scale Collective Intelligences (November 18-22, 2024)
  - Culminating Workshop: Lake Arrowhead Conference Center (December 8-13, 2024)

- Non-commutative Optimal Transport (March 10 - June 13, 2025)
  - Non-commutative Optimal Transport Opening Day (March 10, 2025)
  - Non-commutative Optimal Transport Tutorials (March 11-14, 2025)
  - Workshop I: Optimal Transport for Density Operators: Theory and Numerics (March 31-April 4, 2025)
  - Workshop II: Dynamics of Density Operators (April 28-May 2, 2025)
  - Workshop III: Statistical and Numerical Methods for Non-commutative Optimal Transport (May 19-23, 2025)
  - Culminating Workshop: Lake Arrowhead Conference Center (June 8-13, 2025)

IPAM held the following workshops in the reporting period:

- Rotating Turbulence: Interplay and Separability of Bulk and Boundary Dynamics (January 27-31, 2025)
- Computational Interactions between Algebra, Combinatorics, and Discrete Geometry (February 10-14, 2025)
- Free Entropy Theory and Random Matrices (February 24-28, 2025)

IPAM held the following Thematic Schools:

- Groundwork for Operator Algebras Lecture Series (GOALS) (July 15 – 27, 2024)

Furthermore, the following public lectures were organized during this period:

- Robert Ecke gave the talk "Tales of Rotating Thermal Convection" (January 27, 2025) as part of the *Rotating Turbulence: Interplay and Separability of Bulk and Boundary Dynamics* workshop.
- Green Family Lecture Series: Alessio Figalli two talks, "Optimal Transport: From A to B… and Beyond" (May 19, 2025) and "Exploring Stability in Geometric and Functional Inequalities: OT and Beyond" (May 20, 2025) as part of *Workshop III: Statistical and Numerical Methods for Non-commutative Optimal Transport.*

During the reporting period, IPAM hosted the following special events and conferences:

- NSF Mathematics Institutes' Modern Math Workshop (at SACNAS) (October 30-31, 2024)
- PUMA: Practicum for Undergraduate MAthematicians in Inverse Problems and Data Assimilation (November 23-24, 2024)
- Quantum Winter School: Quantum Error Suppression, Mitigation, and Correction (February 3-5, 2025), organized in collaboration with the NSF Challenge Institute for Quantum Computation (CIQC) and the Advanced Molecular Architectures for Quantum Information Science (AMAQIS).
- Latinx in the Mathematical Sciences Conference 2025 (LatMath) (March 6-8, 2025)
- PUMA: Practicum for Undergraduate MAthematicians in Topology (April 12-13, 2025)

IPAM typically invites participants from each of our past long programs to two reunion conferences; the first is held a year and a half after the conclusion of the long program, and the second is held one year after the first. During the current reporting period, we were able to bring together several of these cohorts for an opportunity to reconnect and reflect on collaborations that followed since they attended the long programs. These conferences along with the culminating workshops were held at the UCLA Lake Arrowhead Conference Center.

- Advancing Quantum Mechanics with Mathematics and Statistics Reunion Conference 2 (December 8-13, 2024)
- New Mathematics for the Exascale: Applications to Materials Science Reunion Conference 1 (December 8-13, 2024)
- Computational Microscopy Reunion Conference 2 (June 9-13, 2025)
- Mathematical and Computational Challenges in Quantum Computing (June 9-13, 2025)

All RIPS and G-RIPS student research programs were held in-person in summer 2024. This report includes all four programs:

- Research in Industrial Projects for Students at IPAM (RIPS), Los Angeles, CA
- Research in Industrial Projects for Students in Singapore (RIPS-SP)
- Graduate-level RIPS (G-RIPS) in Sendai, Japan
- Graduate-level RIPS (G-RIPS) in Berlin, Germany

A. PARTICIPANT LIST

A list of all participants in IPAM programs will be provided to NSF in electronic form (Excel). The list will include participants for programs whose start dates fall between June 14, 2024 through June 13, 2025.

B. FINANCE SUPPORT LIST

A list of participants that received support from IPAM will be provided to NSF in electronic form (Excel). The list includes all funded participants of programs that occurred between June 1, 2024 through May 31, 2025.

C. INCOME AND EXPENDITURE REPORT

Grant # DMS 1925919:

This table shows appropriations and expenses for June 1, 2024 through May 31, 2025 for grant #1925919.

	A	B	C	D	E	F
			A-B=C		B+D=E	A-E=F
Budget Category	Appropriation Year 4	Actual Expenses	Balance	Encumbered Expenses as of May 2025	Total & Encumbered Expenses as of May 2025	Encumbered Balance as of May 2025
A. Operations Fund	$2,003,333	$2,426,507	($423,174)	$236,298	$2,662,805	($659,472)
B. Participant Costs	$1,900,000	$2,633,087	($733,087)	$100,307	$2,733,395	($833,395)
C. Indirect Costs	$1,096,667	$1,097,830	($1,163)		$1,097,830	($1,163)
Totals	**$5,000,000**	**$6,157,474**	**($1,157,424)**	**$336,605**	**$6,494,030**	**($1,494,030)**

During Year 5, Operational Costs (e.g., salaries, benefits, equipment, supplies) were steady at $2,426,507. Participant Support Costs (e.g., stipends, travel, housing, and subsistence for the scientists working on IPAM Programs) were at a healthy level of $2,633,087. Indirect Costs rates are based on current facilities and administrative cost rates negotiated with the Federal

government and the University of California. IPAM's work is conducted at an on-campus location which is subject to a 56% facilities and administrative cost rate. Indirect costs are not applied to equipment and participant support costs.

Registration fees for NSF-supported conferences are accounted for as program income. IPAM charges modest registration fees primarily to discourage non-serious registrations. Registration fees for workshops are $75 for faculty and government/military participants, $100 for industry participants, $50 for post-doctoral scholars and $25 for graduate students. During this reporting period, the in-person workshop registration fees collected were $20,725. All program income collected is spent entirely on participant support expenses.

D. MATH INSTITUTE DIRECTORS' MEETING REPORT

MIDS Meeting 2025

April 25, 2025
Arlington, VA

Meeting Chair: Akshay Venkatesh (IAS)

Present:
AIM: Brian Conrey, Michelle Manes
IAS: Akshay Venkatesh
ICERM: Brendan Hassett, Ulrica Wilson
IMSI: Kevin Corlette, Bo Hammer, Hongmei Jiang, Denise Slavinski
IPAM: Selenne Banuelos, Christian Ratsch, Dima Shlyakhtenko
SLMath: Chris Marshall, Tatiana Toro
NSF: Marian Bocea, Stefaan De Winter, Joanna Kania-Bartoszynska, Stacy Levine, David Manderscheid, Andy Pollington, Junping Wang, Yong Zeng

Agenda:

1. DMS outlook on institutes

   The DMS outlook for the institute is favorable; institutes are a priority. Current NSF priorities were discussed.

2. Update on DMS

   DMS expects to process renewal recommendations as soon as there is clarity on the budget.

3. Update on Spending from the Institutes

   Institutes reported on expected spending through the end of the current year.

4. Timeline for 2025-2030 grants

   DMS expects to have budget clarity in mid-May.

5. Future of broadening participation initiatives at the institutes

   NSF reported on current priorities regarding broadening participation.

6. Guidelines for annual report

   There was discussion of questions regarding DMS expectations for institute annual reports. DMS will get back to the institutes with responses.

7. MathIntitutes.org & the possibility of new institutes

   Once the institute cohort is set, ICERM will re-vamp the math institutes website. Website helps publicize math institutes' impact for Congress, the public, etc. Institutes will submit updated text to DMS for the DMS Research Institutes page.

E. PARTICIPANT SUMMARY

In this report, we are reporting on participants of programs that took place between June 14, 2024 through June 13, 2025. We have included the participants of the reunion conference. This report does not include the participants of our RIPS/G-RIPS 2025 summer programs which will be captured in the next reporting cycle.

We include only in-person participants in all statistical computations.

Participant Category	**Total Participants**
Faculty	759
Government/Military	30
Graduate Student	680
Industry	118
Postdoc	274
Undergraduate Student	253
Other	6
Total Participants	**2120**

Also note that we do not collect RSVPs or collect participants data for “Public Lectures”.

Table E1: Participant Summary	
Program type	Total Participants
Board Meetings	36
Long Programs	128
Reunion Conferences	97
Special Events and Conferences	433
Student Research Programs	198
Subworkshops	104
Summer Schools	40
Workshops	1084
Total	**2120**

F. POSTDOCTORAL PROGRAM SUMMARY

A total of 274 postdocs participated in IPAM's programs during the reporting period (June 14, 2024 - June 13, 2025). See table F1 below for a summary of postdoctoral participation by program type.

Table F1: Postdoctoral Summary	
Program type	Total Participants
Long Programs	19
Reunion Conferences	27
Special Events and Conferences	34
Student Research Programs	6
Subworkshops	18
Summer Schools	2
Workshops	168
Total	**274**

G. GRADUATE STUDENT PROGRAM SUMMARY

As with previous years, a robust number of graduate students participated in IPAM's workshops and long programs during the reporting period, as well as in Graduate-level RIPS. A few participated in RIPS-LA as academic mentors. Graduate students often find a compelling thesis topic at an IPAM program, and also frequently make contacts that lead to their first jobs. See table G1 below for a further breakdown of the graduate student participation by program type.

Table G1: Graduate Student Summary	
Program type	**Total Participants**
Long Programs	40
Reunion Conferences	34
Special Events and Conferences	141
Student Research Programs	26
Subworkshops	35
Summer Schools	13
Workshops	391
Total	680

H. UNDERGRADUATE STUDENT PROGRAM SUMMARY

Typically, undergraduate students participate in RIPS-LA, RIPS-Singapore, and RIPS Projects Day. However, we saw a number of undergraduate students attend other programs at IPAM during the reporting period. Please see Table H1 below for a summary of the undergraduate participants by program type.

Table H1: Undergraduate Summary	
Program type	Total Participants
Special Events and Conferences	141
Student Research Programs	112
Total	253

I. PROGRAM DESCRIPTION

STUDENT RESEARCH PROGRAM

Graduate Research in Industrial Projects for Students (G-RIPS), Berlin, Germany

June 24 - August 16, 2024

Graduate-Level Research in Industrial Projects for Students (G-RIPS) in Berlin offers graduate students in mathematics and related disciplines the opportunity to work on industry-sponsored research problems. Students from the U.S. and Germany work on cross-cultural teams on three research problems designed by the industrial sponsor. The projects are of serious interest to the sponsor and offer a stimulating challenge to students; most involve both analytic and computational work. At the end of the program, the teams present the results of their work and prepare a final report. English is the only language required for participation.

Round-trip travel to Berlin and accommodations in Berlin are included. Students also receive a meal allowance and a stipend of $4,200. (These terms apply to U.S. participants recruited by IPAM.)

Six U.S. students participated in G-RIPS Berlin in 2024 together with four European students. Each team consists of two US students and two European students. The students worked on projects that were sponsored by some of the most important companies in Germany. This year, the list of industrial partners included Thermo Fisher Scientific, JCMwave GmbH, and TBD.

2024 INDUSTRY PARTNERS	**PROJECT TITLES**
Thermo Fisher Scientific (MedLab)	Cryo-electron tomography and deep learning for analyzing sub-cellular structure
TBD (Energy Lab)	Flow instabilities in wind energy systems
JCMwave GmbH (NanoLab)	Machine learning for optimizing numerical settings of finite-element based optics simulations

Thermo Fisher Scientific – MedLab Project

Project Title: Cryo-electron tomography and deep learning for analyzing sub-cellular structure
Project Description: Cryo-electron tomography (CET) is the only imaging technique that allows observing three-dimensional (3D) information of subcellular structures directly in their native context in a near-atomic resolution. Due to several physical limitations of the acquisition process, multiple instances of the same protein need to be identified and averaged to reveal the structure, a process called sub-tomogram averaging (STA). However, identification as well as location and orientation approximation of single macromolecules in tomography data using currently available software is still the bottleneck. This is due to a substantial amount of user interaction required for annotating the data being a time-consuming and error prone process. Recently, particle picking in crowded cell environments of CET images was improved using automated methods like deep learning (DL) [1,2]. DL, on the other hand, requires training with

large amounts of annotated data which in the case of STA imposes an insurmountable obstacle. As a result, some challenges like particle orientation approximation have not been addressed. One potential solution to the annotation problem is the use of simulated tomograms bringing the annotations for free. However, the discrepancy between synthetic and real sample distribution, namely the domain gap, significantly reduces the performance of models trained on synthetic data with experimental data. To this end, in this project, we will investigate DL-based models that predict particle orientation from synthetic data. While such models have a successful performance on unseen synthetic test data, results are still poor on experimental data. Therefore, we will investigate how fine-tuning the embedding feature space learned by a pretrained model can be done. For this, we will explore how the transfer of knowledge from simulated to experimental data can be achieved without retraining the whole model from scratch or requiring large amounts of annotated experimental data.

JCMwave GmbH Project

Project Title: Machine learning for optimizing numerical settings of finite-element based optics simulations
Project Description: Photonics is a key enabling technology of the 21st century. Data-based methods play an essential role in the development and application of photonic and quantum technologies. In areas such as sensor technology and quality control, the evaluation of data enables decision-making and quantification processes. In addition to model-based simulations of measurement processes, artificial intelligence (AI) methods are becoming increasingly important here. The MODAL NanoLab is developing methods for efficient, error-controlled and self-adaptive simulation of light-matter interactions in optical nanostructures. Efficient tuning of accuracy settings of numerical simulations is of crucial importance for the fidelity and interpretability of the corresponding simulation results. For finite-element based simulations, these settings relate to mesh quality, mesh density, polynomial degree of the finite-element ansatz functions, and other parameters. The goal of this GRIPS project is to investigate ML methods for finding optimal parameter settings. This should then replace the laborious task of manually adjusting accuracy parameters.In the proposed MODAL GRIPS2024 project, participants will get hands-on experience with the commercial programme package JCMsuite, containing a finite-element solver an optimizer based on a Bayesian formalism. We will use machine learning to find the optimal JCMsuite execution times for the problem of practical interest while treating the desired precision of the final numerical result as an outcome constraint during optimization runs. In this way, we will completely automatize the search process for the optimal finite-element accuracy settings.

LBW

Project Title: Flow instabilities in wind energy systems
Project Description: Integrating renewable energy sources, such as wind power, is critical for sustainable energy production. Wind farms comprising multiple turbines face challenges related to wake interactions that can significantly impact overall efficiency. Flow instabilities, e.g., the Kelvin-Helmholtz instability (KHI), a hydrodynamic phenomenon that occurs when two fluids of different densities flow past each other with different velocities, may play a crucial role in shaping wind farm wakes. The instability of wind flows around wind turbines may form vortices

and thus reduce the efficiency of turbines. Understanding and mitigating these instabilities is essential for optimizing wind farm layouts and enhancing energy extraction.

STUDENT RESEARCH PROGRAM

Graduate Research in Industrial Projects for Students (G-RIPS), Sendai, Japan

June 18 - August 8, 2024

Graduate-Level Research in Industrial Projects for Students (G-RIPS) in Japan offers graduate students in mathematics and related disciplines the opportunity to work on industry-sponsored research problems in Sendai, Japan. Students from the U.S. and Japan work on cross-cultural teams on research problems designed by industrial sponsors. The projects are of serious interest to the sponsor and offer a stimulating challenge to students; most involve both analytic and computational work. At the end of the program, the teams present the results of their work and prepare a final report. IPAM encourages the U.S. students to publish and/or present their research at conferences in the year following the program. English is the only language required for participation.

Round-trip travel to Sendai and accommodations in Sendai are included. Students also receive a meal allowance and a stipend of $4,200, and conference support to present their research. (These terms apply to U.S. participants recruited by IPAM.)

Eight U.S. students participated in G-RIPS Sendai in 2024 together with eight Japanese students. Each team consisted of two US students and two Japanese students. The students worked on projects that were sponsored by some of the most important companies in Japan. This year, the list of industrial partners included Mitsubishi, Fujitsu, and IHI.

2024 INDUSTRY PARTNERS	**PROJECT TITLES**
Mitsubishi-A	Exploration of Useful Geometric Structures for Object Recognition using Point Clouds
Mitsubishi-B	Achievable precision with heuristic solvers: quantum algorithms and quantum supremacy
Fijitsu	Enhancing explainability of causal discovery AI
IHI	Resilient water management modeling against global warming and for sustainable food supply

Mitsubishi Project A

Project A Title: Exploration of Useful Geometric Structures for Object Recognition using Point Clouds

Project A Description: Mitsubishi Electric (Mitsubishi Electric Global Website) founded in 1921, is an electrical and electronic equipment manufacturer, developing products and solutions in widely diverse fields, including home appliances, industrial equipment, and space technologies. The Advanced Technology R&D Center was established to support the business of Mitsubishi Electric Group through the development of a broad scope of projects covering both basic and new advanced technologies. The main research themes include power electronics,

mechatronics, satellite communications, next generation key devices, system solutions for electric power, transportation, factory automation, and automobiles.

Mitsubishi Project B

Project B Title: Achievable precision with heuristic solvers: quantum algorithms and quantum supremacy.
Project B Description: Mitsubishi Electric is a world leader in manufacturing and sales of electrical and electronic products and systems used in a broad range of fields and applications. As a global leader among green companies, our technologies are being applied to contribute to and support society and daily life around the world. The Information Technology R&D Center is actively creating new businesses through basic research and development in the fields of information technology, media intelligence, electro-optics microwaves, and communication technologies. We are also seeking technologies that reinforce our position on the leading edge of progress, with work to renew existing businesses through the fruits of our R&D in the field of IT.

Fijitsu

Project title: Enhancing explainability of causal discover AI.
Project description: The Fujitsu Group provides digital services globally, with operations in different regions around the world, including Japan. Fujitsu's Information Technology (IT) services business ranks at the top by market share in Japan and is in the top tier worldwide: a record that reflects our outstanding technologies and long track record in building large-scale, cutting-edge systems.

IHI Project

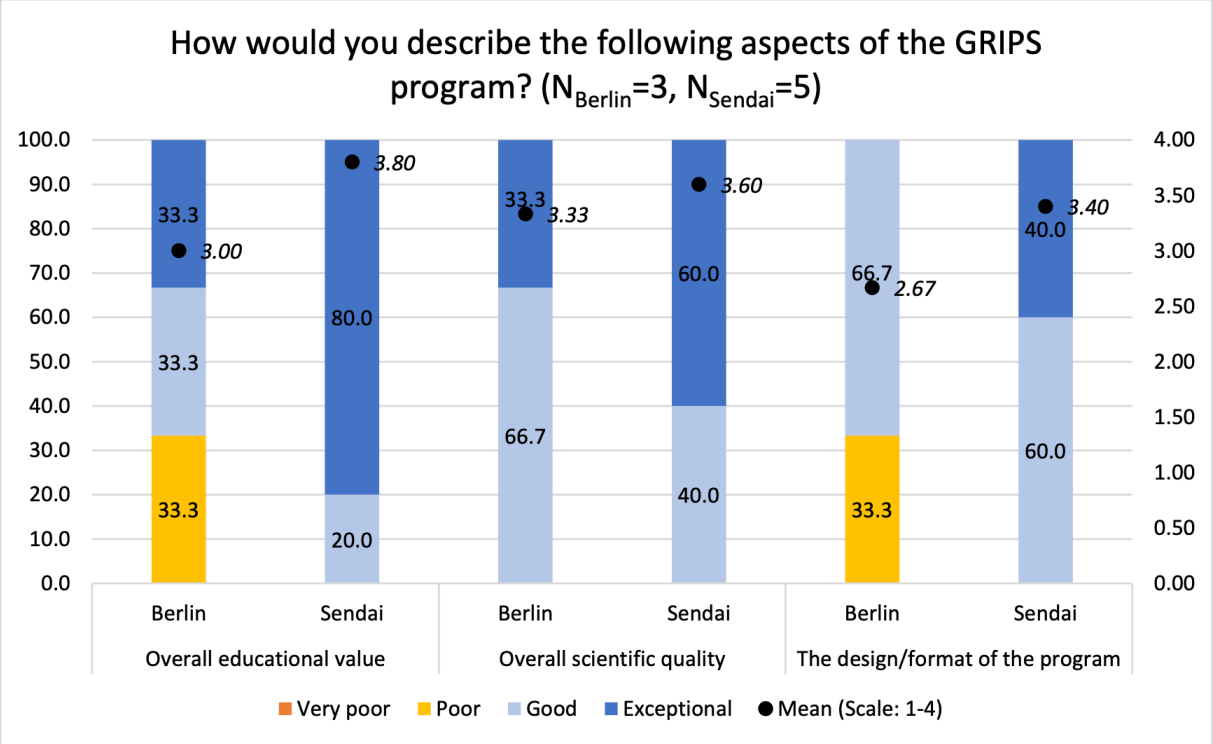
Project title: Mathematics for trajectory extrapolation using vehicle and human traffic data toward zero traffic fatalities.
Project description: IHI has developed a unique LiDAR sensor (3D Laser Radar) to support automation of industrial machinery in harsh environments with poor visibility. In this project, students will use LIDAR data to analyze and predict vehicle trajectories with the goal of improving the safety of traffic systems.

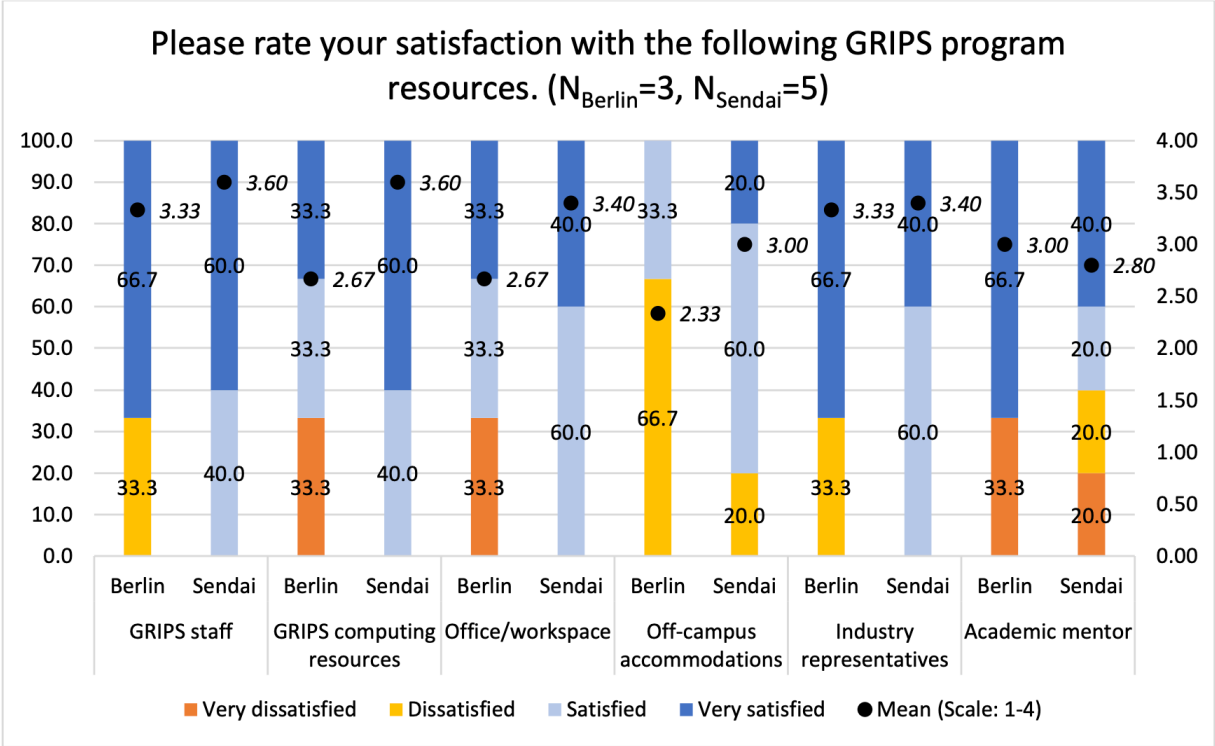
NEC Project

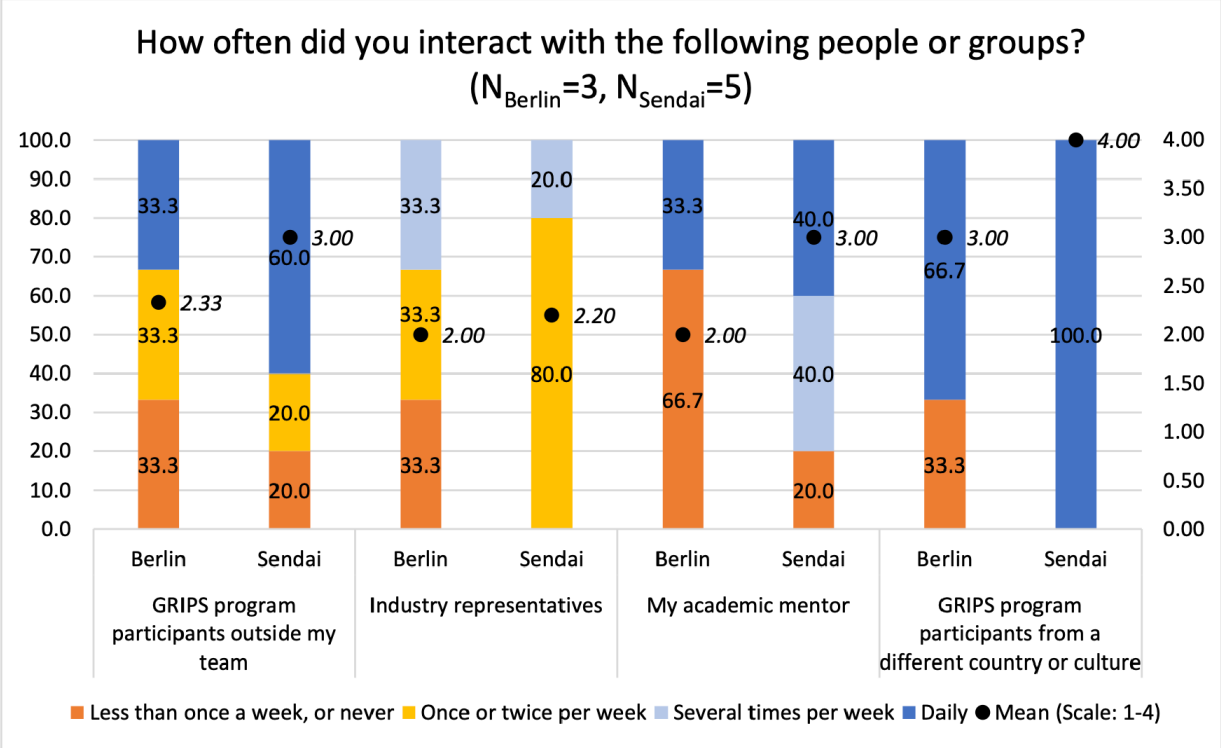
Project title: Resilient water management modeling against global warming and for sustainable food supply
Project description: IHI Corporation (formerly Ishikawajima Harima Heavy Industries Corporation) is a comprehensive heavy-industry manufacturer, with a history extending back to the establishment of Ishikawajima Shipyard, Japan's first modern shipbuilding facility, in 1853. The technology which began with shipbuilding has been passed on to develop and improve social infrastructure and industrial machinery, with expansion of the IHI Corporation business domain from sea to land and space. We will continue to respond flexibly to social changes and to aim for sustainable development.

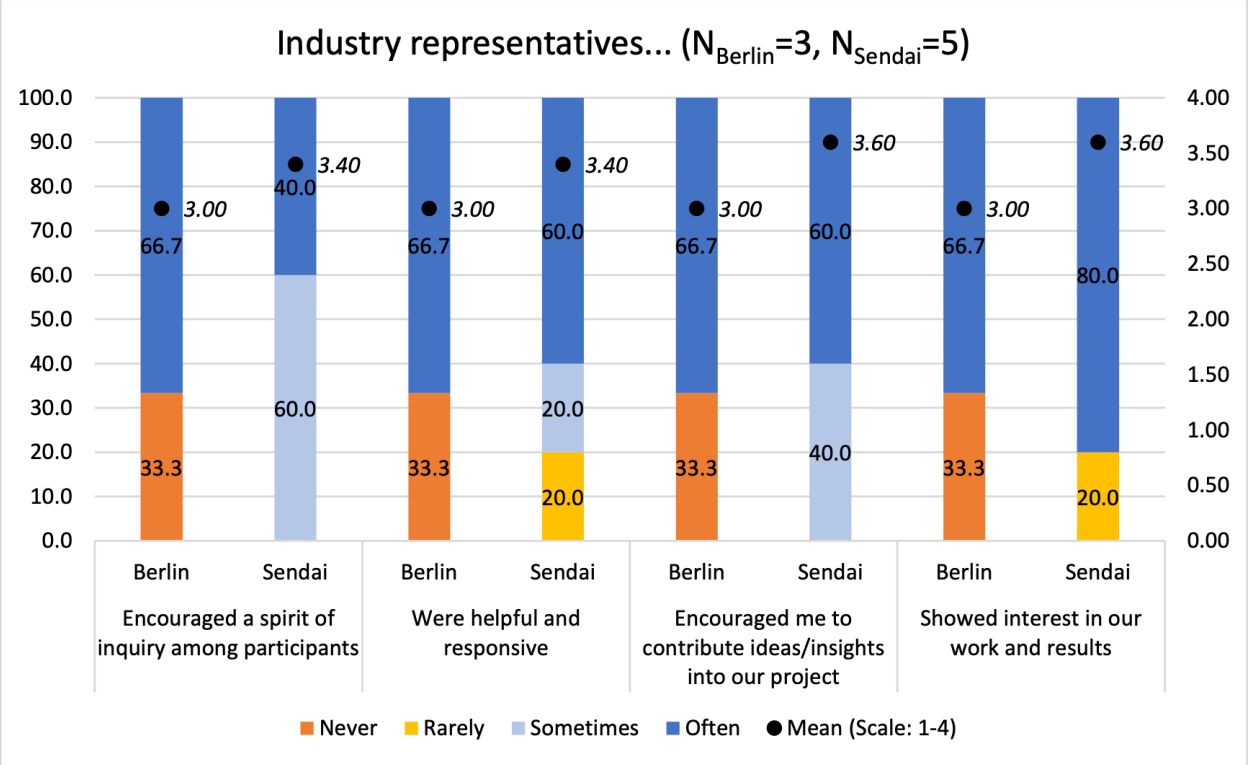
G-RIPS 2024 Participant Survey Results

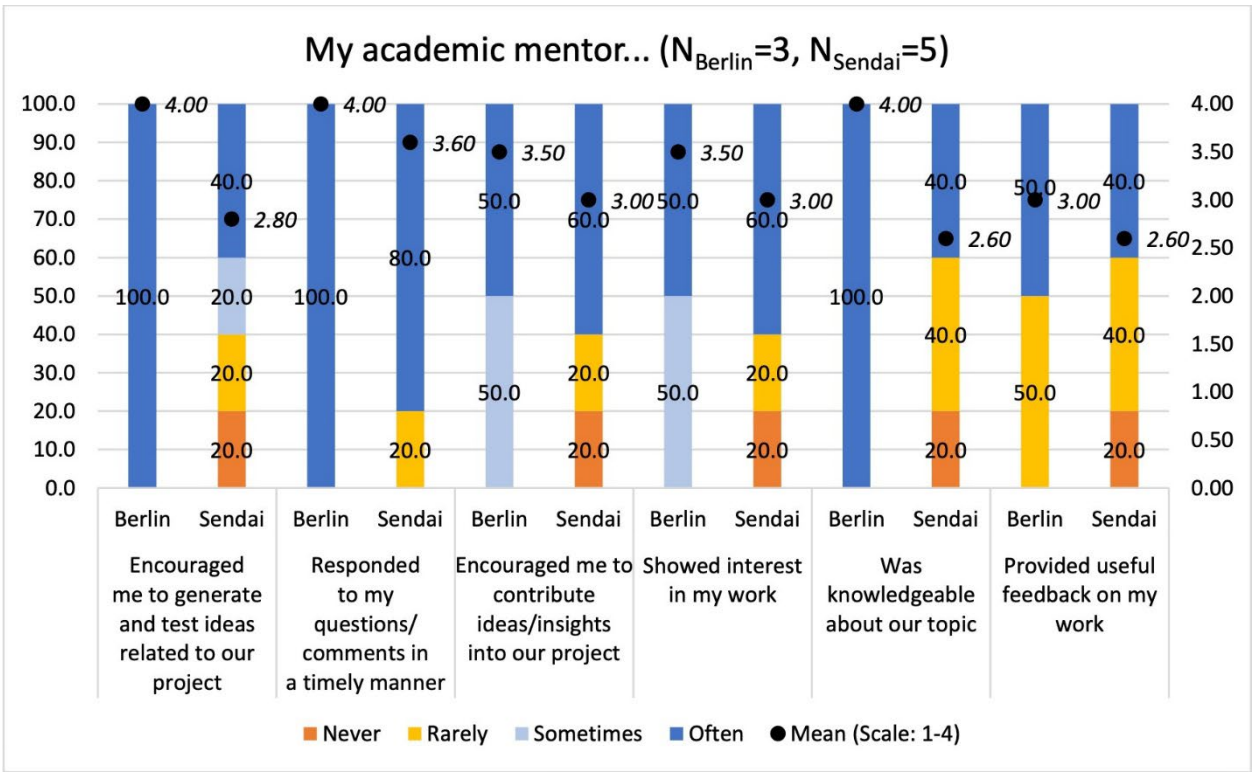
IPAM surveys G-RIPS participants (both Berlin and Sendai) both pre- and post-participation. They surveys are designed to elicit feedback from participants as well as to gauge the effectiveness of the program. A total of 13 Berlin and Sendai G-RIPS participants responded to surveys (10 pre-program, 8 post-program), with 5 completing both the pre- and post-program surveys. Chart data are disaggregated by campus and summarize their respective response frequencies and mean response scores.

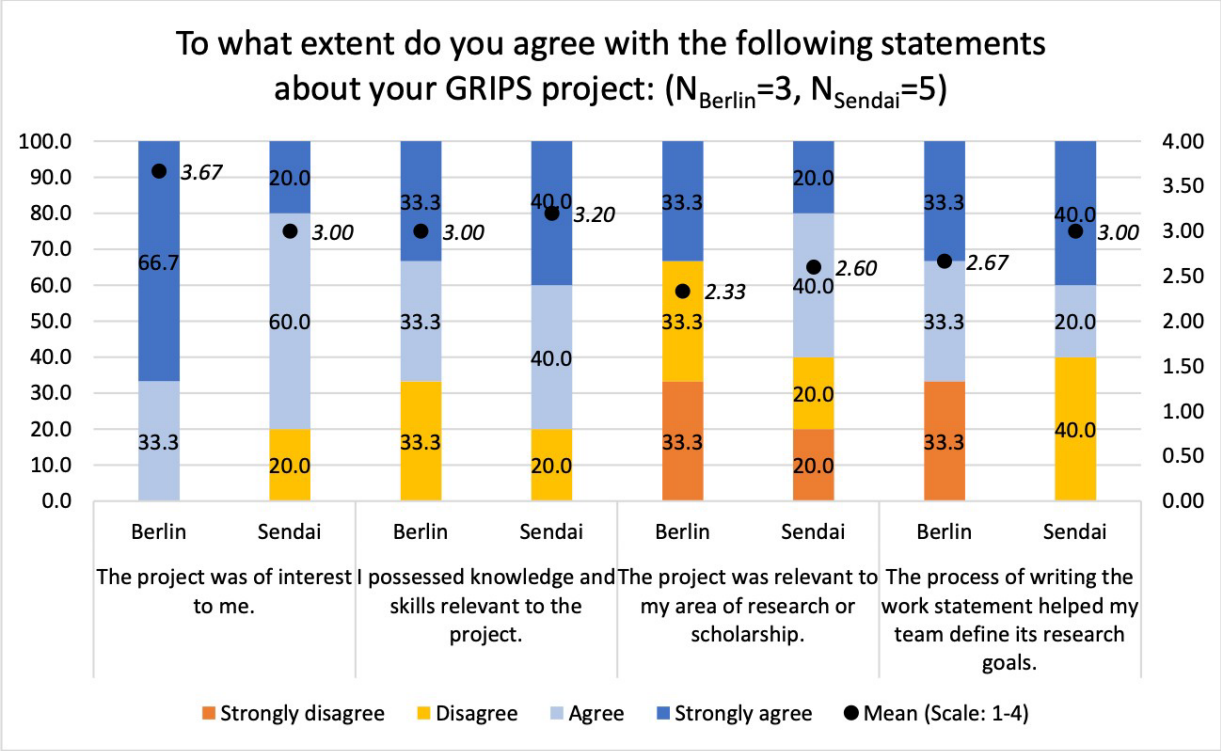


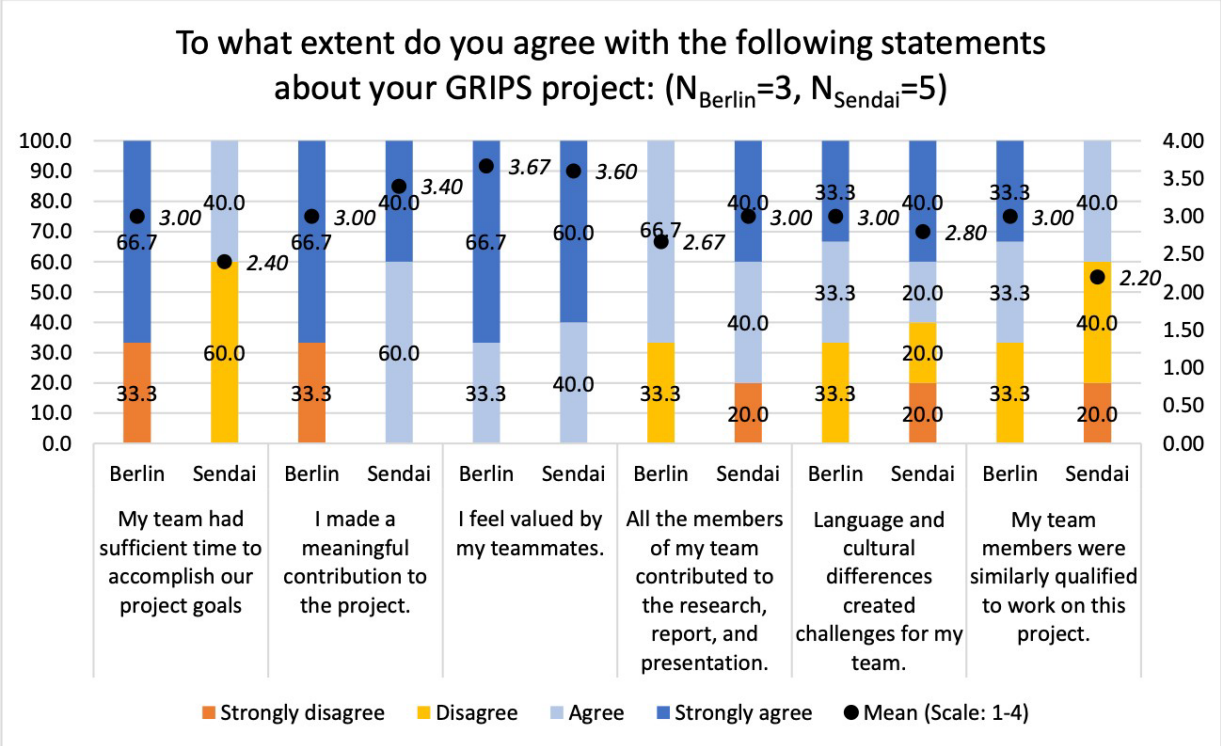

Please rate your satisfaction with the following GRIPS program resources. (N_{Berlin}=3, N_{Sendai}=5)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.33
3.60
3.60
3.40
3.33
3.00
3.33
3.40
3.00
2.80
2.67
2.67
2.33
66.7
60.0
33.3
40.0
33.3
40.0
33.3
60.0
33.3
20.0
60.0
66.7
40.0
60.0
66.7
40.0
20.0
33.3
33.3
33.3
33.3
20.0
33.3
20.0
Berlin
Sendai
GRIPS staff
GRIPS computing resources
Office/workspace
Off-campus accommodations
Industry representatives
Academic mentor
Very dissatisfied
Dissatisfied
Satisfied
Very satisfied
Mean (Scale: 1-4)

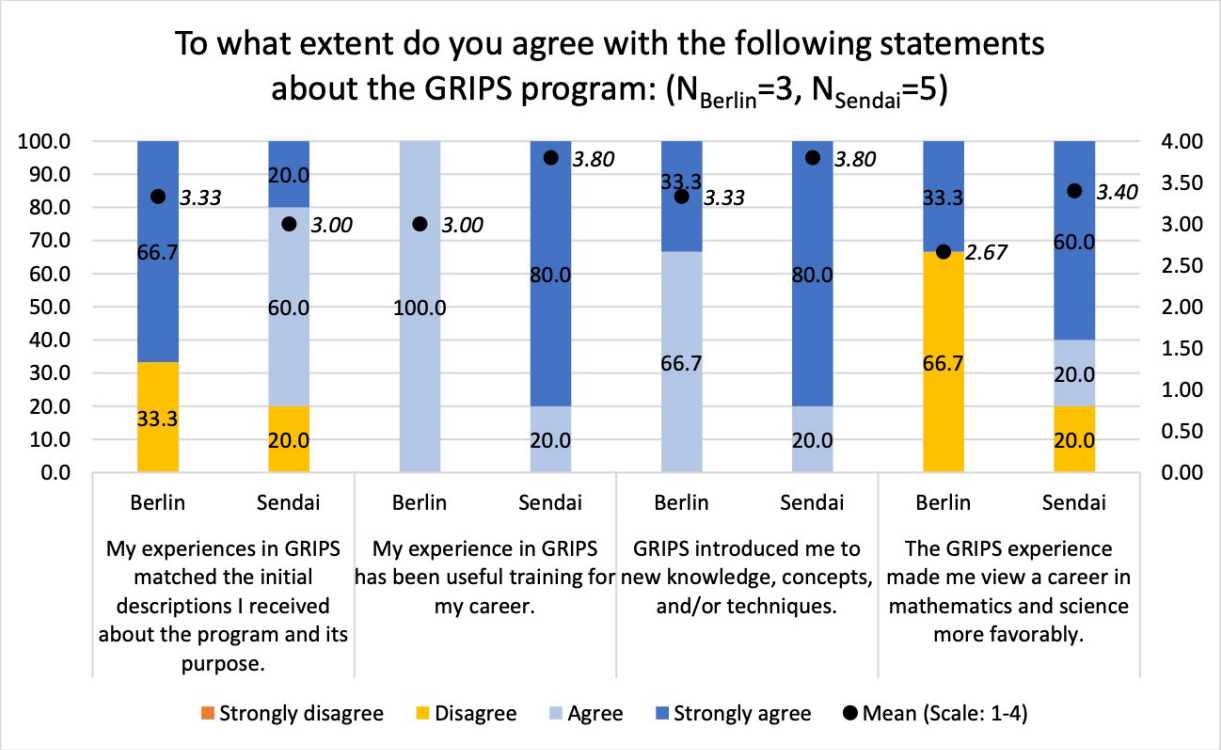

How often did you interact with the following people or groups? (N_{Berlin}=3, N_{Sendai}=5)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2.33
3.00
2.00
2.20
2.00
3.00
3.00
4.00
33.3
33.3
33.3
60.0
20.0
20.0
33.3
33.3
33.3
20.0
80.0
33.3
66.7
40.0
40.0
20.0
66.7
33.3
100.0
Berlin
Sendai
GRIPS program participants outside my team
Industry representatives
My academic mentor
GRIPS program participants from a different country or culture
Less than once a week, or never
Once or twice per week
Several times per week
Daily
Mean (Scale: 1-4)


Industry representatives... (N_{Berlin}=3, N_{Sendai}=5)
Berlin
Sendai
Encouraged a spirit of inquiry among participants
Were helpful and responsive
Encouraged me to contribute ideas/insights into our project
Showed interest in our work and results
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)


My academic mentor... (N_{Berlin}=3, N_{Sendai}=5)
Berlin
Sendai
Encouraged me to generate and test ideas related to our project
Responded to my questions/ comments in a timely manner
Encouraged me to contribute ideas/insights into our project
Showed interest in my work
Was knowledgeable about our topic
Provided useful feedback on my work
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)


To what extent do you agree with the following statements about your GRIPS project: (N_{Berlin}=3, N_{Sendai}=5)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.67
66.7
33.3
3.00
20.0
60.0
20.0
3.00
33.3
33.3
33.3
3.20
40.0
40.0
20.0
2.33
33.3
33.3
33.3
2.60
20.0
40.0
20.0
2.67
33.3
33.3
33.3
3.00
40.0
20.0
40.0
Berlin
Sendai
Berlin
Sendai
Berlin
Sendai
Berlin
Sendai
The project was of interest to me.
I possessed knowledge and skills relevant to the project.
The project was relevant to my area of research or scholarship.
The process of writing the work statement helped my team define its research goals.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


To what extent do you agree with the following statements about your GRIPS project: (N_{Berlin}=3, N_{Sendai}=5)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.00
66.7
33.3
40.0
2.40
60.0
3.00
66.7
33.3
3.40
40.0
60.0
3.67
66.7
33.3
3.60
60.0
40.0
66.7
33.3
2.67
3.00
40.0
40.0
20.0
3.00
33.3
33.3
33.3
2.80
40.0
20.0
20.0
3.00
33.3
33.3
33.3
2.20
40.0
40.0
20.0
Berlin
Sendai
Berlin
Sendai
Berlin
Sendai
Berlin
Sendai
Berlin
Sendai
Berlin
Sendai
My team had sufficient time to accomplish our project goals
I made a meaningful contribution to the project.
I feel valued by my teammates.
All the members of my team contributed to the research, report, and presentation.
Language and cultural differences created challenges for my team.
My team members were similarly qualified to work on this project.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


To what extent do you agree with the following statements about the GRIPS program: (N_{Berlin}=3, N_{Sendai}=5)
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1.50
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0.50
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20.0
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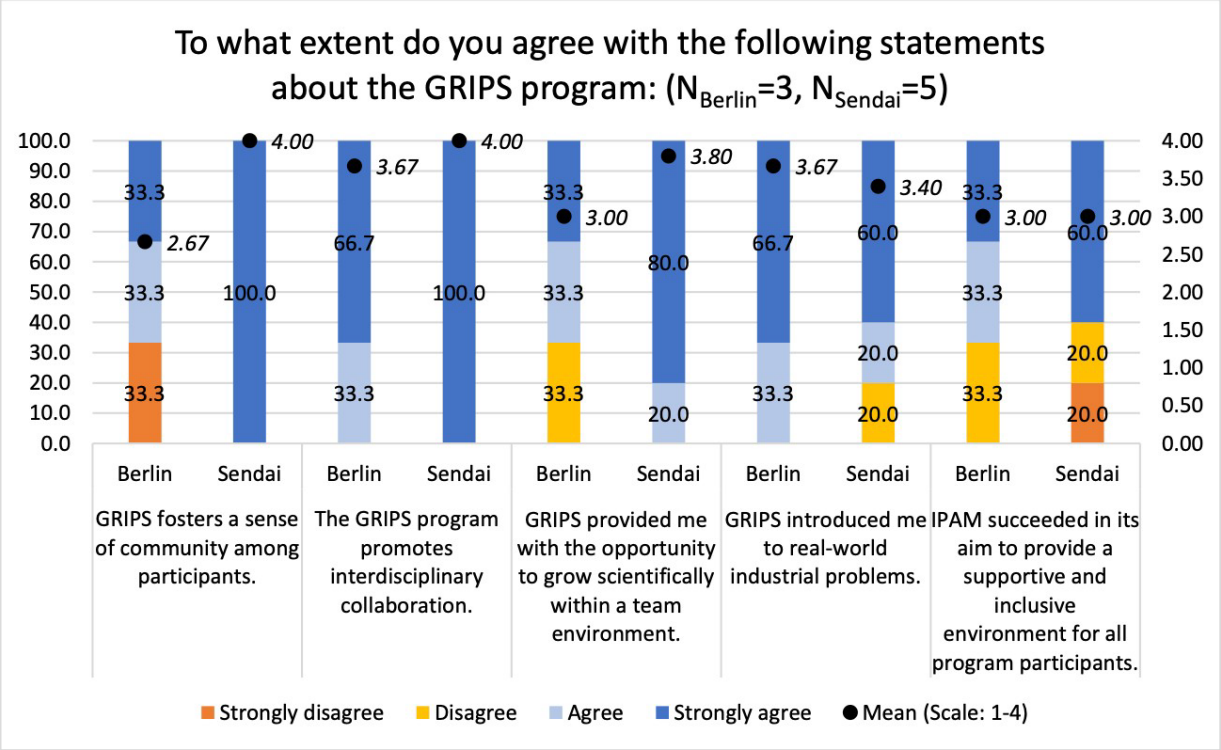
20.0
3.00
100.0
3.80
80.0
20.0
3.33
33.3
66.7
3.80
80.0
20.0
33.3
2.67
66.7
3.40
60.0
20.0
20.0
Berlin
Sendai
My experiences in GRIPS matched the initial descriptions I received about the program and its purpose.
My experience in GRIPS has been useful training for my career.
GRIPS introduced me to new knowledge, concepts, and/or techniques.
The GRIPS experience made me view a career in mathematics and science more favorably.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


To what extent do you agree with the following statements about the GRIPS program: (N_{Berlin}=3, N_{Sendai}=5)
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3.40
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33.3
3.00
33.3
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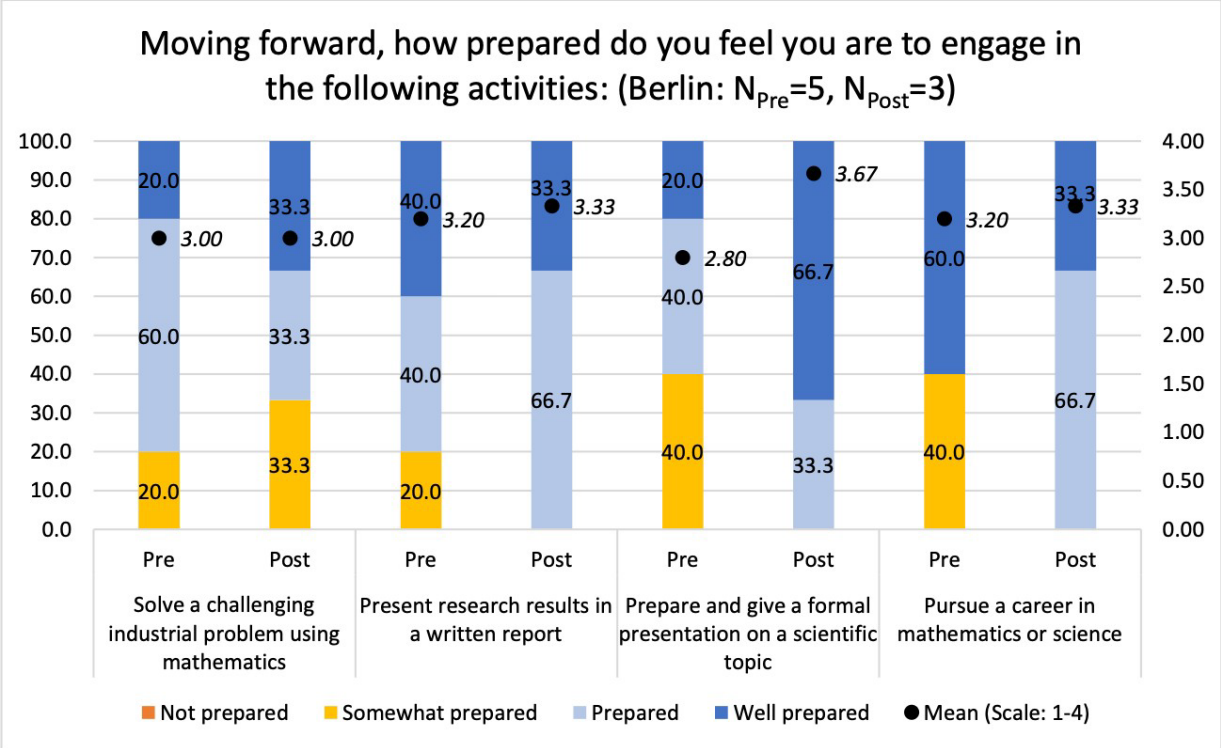
Berlin
Sendai
GRIPS fosters a sense of community among participants.
The GRIPS program promotes interdisciplinary collaboration.
GRIPS provided me with the opportunity to grow scientifically within a team environment.
GRIPS introduced me to real-world industrial problems.
IPAM succeeded in its aim to provide a supportive and inclusive environment for all program participants.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


Moving forward, how prepared do you feel you are to engage in the following activities: (Berlin: N_Pre=5, N_Post=3)
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40.0
40.0
2.80
66.7
33.3
3.67
60.0
40.0
3.20
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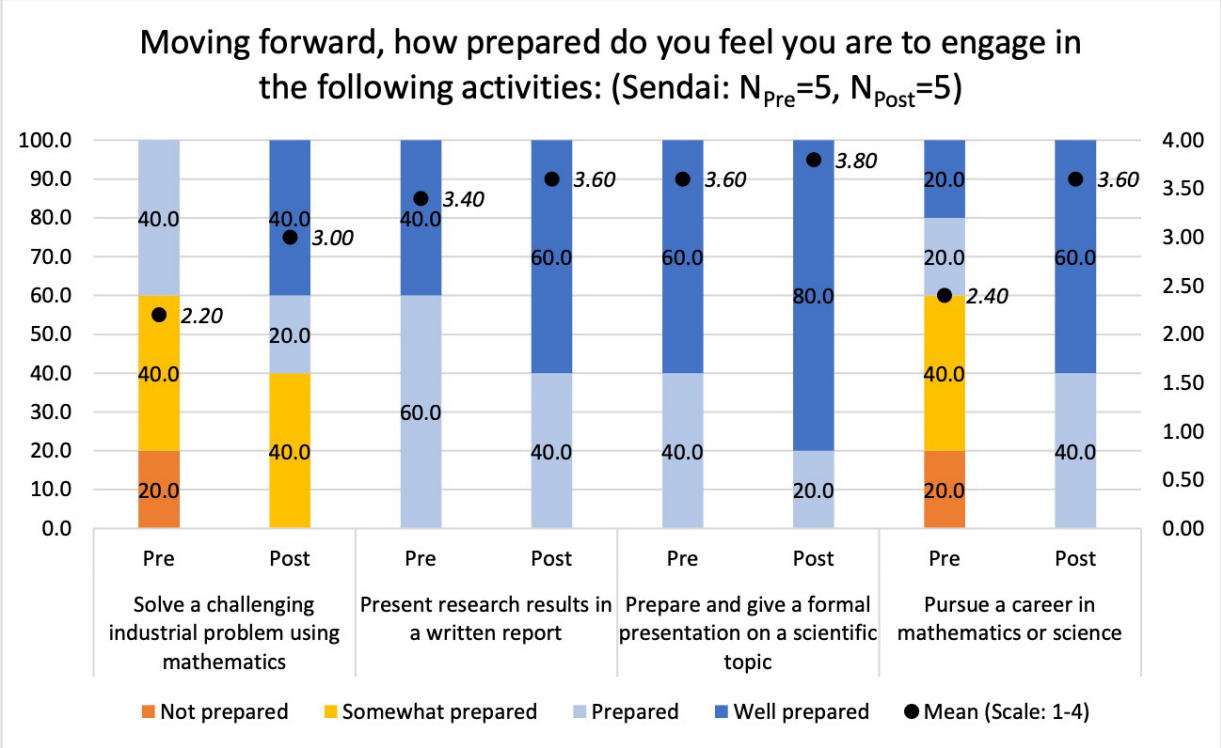
Pre
Post
Pre
Post
Pre
Post
Pre
Post
Solve a challenging industrial problem using mathematics
Present research results in a written report
Prepare and give a formal presentation on a scientific topic
Pursue a career in mathematics or science
Not prepared
Somewhat prepared
Prepared
Well prepared
Mean (Scale: 1-4)


Moving forward, how prepared do you feel you are to engage in the following activities: (Sendai: N_Pre=5, N_Post=5)
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Pre
Post
Pre
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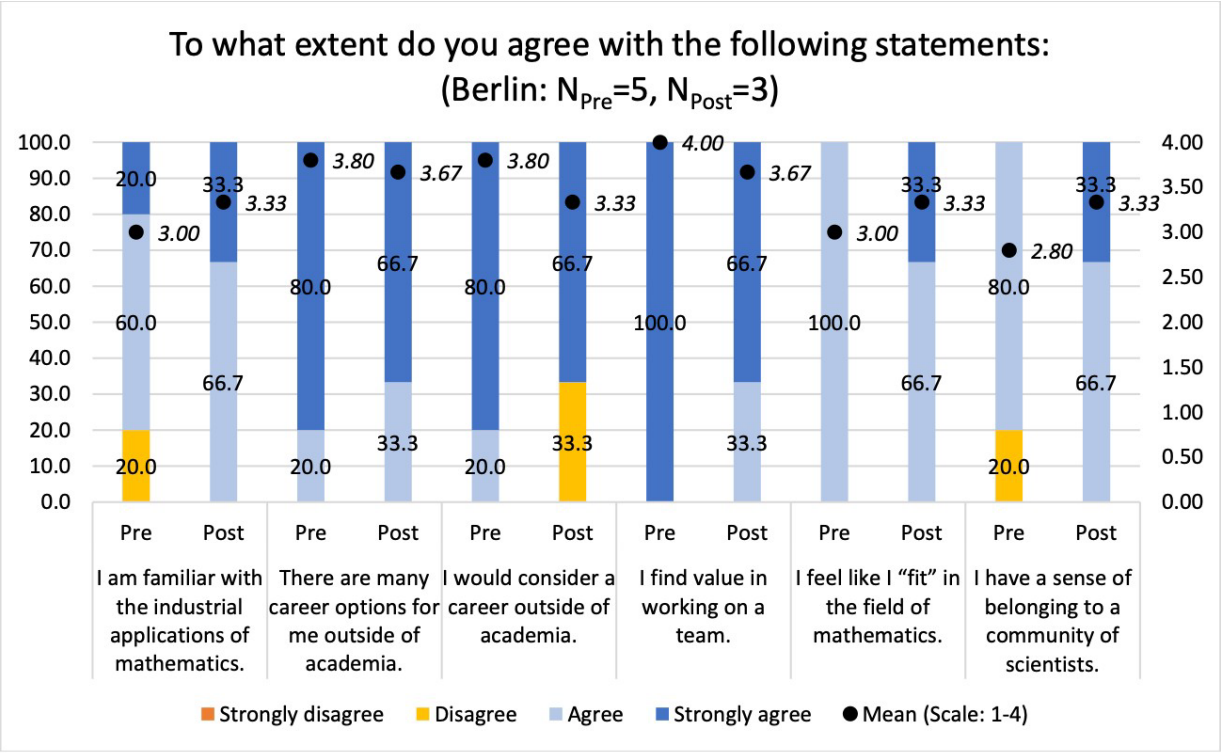
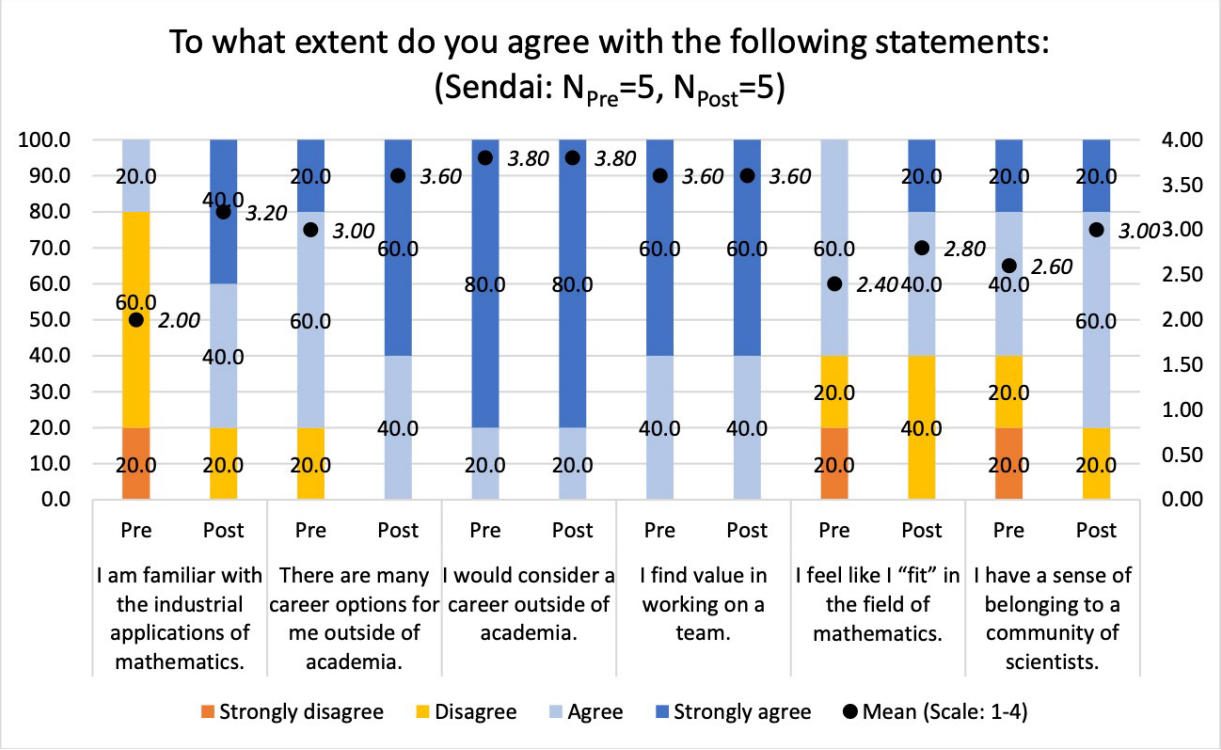
Pre
Post
Pre
Post
Solve a challenging industrial problem using mathematics
Present research results in a written report
Prepare and give a formal presentation on a scientific topic
Pursue a career in mathematics or science
Not prepared
Somewhat prepared
Prepared
Well prepared
Mean (Scale: 1-4)


To what extent do you agree with the following statements:
(Berlin: N_{Pre}=5, N_{Post}=5)
I am familiar with the industrial applications of mathematics.
There are many career options for me outside of academia.
I would consider a career outside of academia.
I find value in working on a team.
I feel like I "fit" in the field of mathematics.
I have a sense of belonging to a community of scientists.
Pre
Post
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)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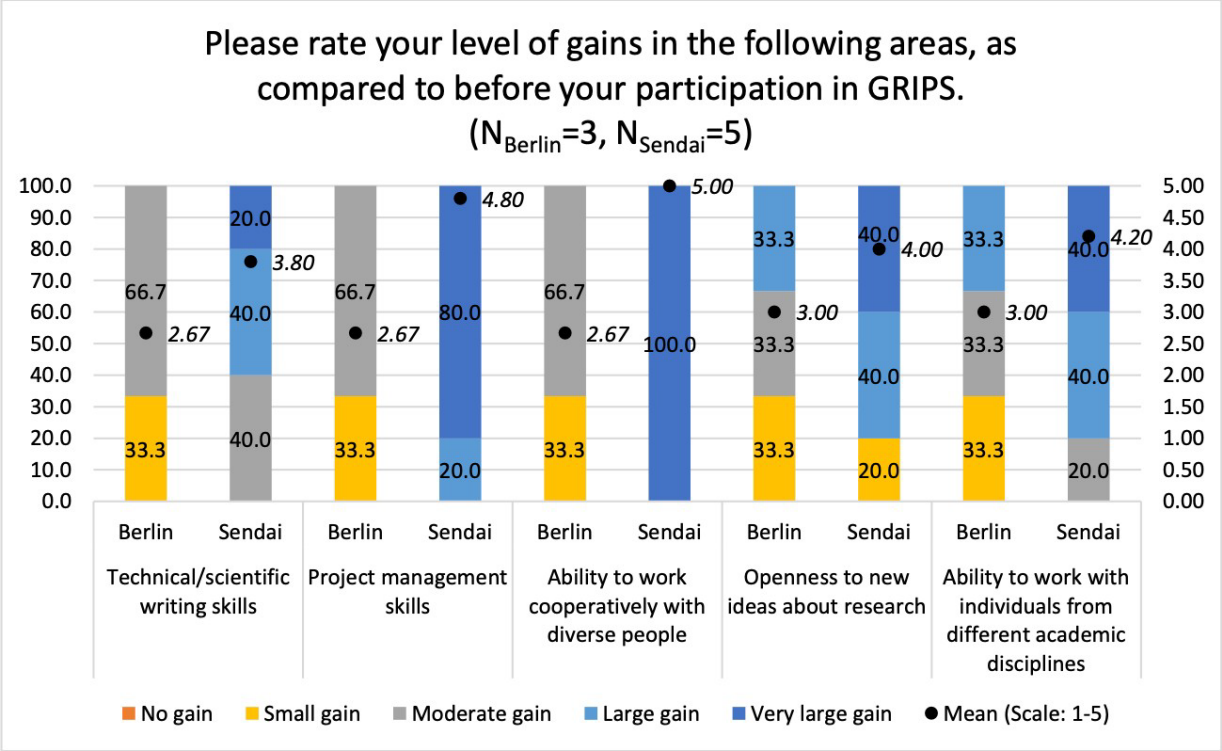
I feel like I "fit" in the field of mathematics.
I have a sense of belonging to a community of scientists.
Pre
Post
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)



Comments from our Student survey:

- I feel that the NanoLab provided an incredible working environment for my team both in terms of mentorship and support. My working and learning experience was exceptional. I feel that the living arrangements could be improved. Most of us are in our late 20s or early 30s and are already adults living on our own. It complicates things to live in the same hotel room, just inches from your coworker that you then see at work for another 8 hours. We were constantly sick from living and working so closely together and some other teams reported deep interpersonal issues that stemmed from such close living proximity. I would recommend suite style living where kitchens and common space are shared but living quarters are separate, or at the very least room people with someone other than their direct coworkers. I also feel like the timeline for reimbursement/payment made it difficult to enjoy this program fully. I am still waiting for final reimbursement and stipend payout almost a month after completing this program. If there is any way to make this happen more quickly for people in the future I know folks would be grateful. Many of us funded our summers with savings and loans from parents which is less than ideal if you want to experience a new culture and explore the city. Overall, I want to say thank you to everyone that made this program possible through IPAM. It was a good experience and I'll be excited to advertise GRIPS to other students at my school.
- I felt that in our team of 4, only 2 of us were making meaningful contributions to the progress of the project (the other two didn't have the required background), and while I fully agree that one purpose of this program is to learn new things, I still think it's important for all team members to have somewhat equal amounts of contributions.

- I think everything I had was fantastic in the project. But the topic of the project is a little bit far from all the team members, and we had very difficult starting times. I hope we can have some supportive document before the start of the program, so we could prepare the program and get smooth starts.
- I think more care should have been taken by IPAM and GRIP S to ensure that the projects assigned to interns are feasible in scope. Our team was very discouraged by the fact that our project was essentially impossible to complete without HPC access, much less the fact that we were never provided with computers or a real office space for the duration of the program. Our team worked on our own personal laptops in a spare room two floors below the rest of the Energy Lab staff, with almost no interaction between us and the host institution. Our academic mentor was also not in Berlin for the final presentation, so our last week we prepared our final report with a brand new mentor. I also think that IPAM could do a better job communicating about the distribution of payment. Interns from the US received an email to set up a Payment Works account while in Germany, but many of us were unable to set up the account to receive payment due to the fact that two-factor authentication via phone is not possible with an eSIM or travel SIM card. I would have preferred to have set up payment information prior to the program's start date instead of halfway through. Most US interns are still waiting for the promised per-diem meal stipend as well as travel compensation. There has been little communication from IPAM on when to expect this payment. While I understand that the housing situation in Berlin is difficult, the living accommodations this summer were a little uncomfortable. I understand that this is an ambiguity of translation, but I did not expect that having a "roommate" for the summer would entail sharing a room with a coworker on the same project. My expectation was that I would share an apartment-style hotel suite with separate bedrooms. Had I known more about the true nature of the hotel, I probably would have paid more to reserve a separate room. For some of the teams, coworkers sharing a living space led to poor working conditions. Were it necessary to share a room, I would have preferred to "leave work at work" and be assigned a room with someone on a different project. Thankfully my roommate and I did not have too many disagreements, but he got very sick halfway through the summer. I felt bad that in addition to feeling sick, my roommate was a little bit ashamed to feel sick around his coworker at work and at home.
- My team was very lucky to have an exceptional team who all worked together very well (including students, academic mentor, and industrial mentors). I feel that we made meaningful contributions through our work and had a great work-life balance. Perhaps the only thing that I would suggest is looking into other options for accommodation, as the hotel we stayed at had a little mold in some rooms that may have caused some students to get sick. However, other than that, I had a great experience there.
- The program's structure was a strong point. I appreciated that we were never "left to our own" for too long. There were research milestones, language & culture classes, and social (networking) activities. Also, Sendai had plentiful food options that were affordable give our food budget. So, I ate lunch with my team every day which helped us to bond. The director Suito-sensei was phenomenal as well—he encouraged us to work hard and play hard and often offered ideas for cultural activities in Sendai. When we organized a sushi night, he brought us sake. When we organized a movie night, he brought Japanese sweets. I felt that he really cared that we have a positive experience in Sendai. I also

gained a lot from the AIMR professor who gave us tips on presentation skills. One area for improvement is the choice of academic mentors - I felt the mentors who were G-RIPS alumni were more helpful and engaged with their team. In future (especially as the program continues and produces more alumni), a mix of American (or non-Japanese) and Japanese alumni could serve as academic mentors.

STUDENT RESEARCH PROGRAM

Research in Industrial Projects for Students (RIPS), Los Angeles, California

June 24 - August 23, 2024

The Research in Industrial Projects for Students (RIPS) Program provides an opportunity for talented undergraduates studying math, computer science, and related disciplines to work in teams on a real-world research project proposed by sponsors from industry or the public sector. The student team, with support from their academic mentor and industry mentor, will research the problem and present their results, both orally and in writing, at the end of the program. The REU program is nine weeks. IPAM provides each undergraduate student with a stipend of $4,000.

Round-trip travel and accommodations costs are covered by IPAM. Students also receive a meal allowance and a stipend, and conference support to present their research. These terms apply to U.S. participants recruited by IPAM. A total of 36 students participated in the RIPS Los Angeles program.

2024 INDUSTRY PARTNERS	PROJECT TITLES
Aerospace Corp.	Optimal Diffusion Kalman Filter for Lunar Time Synchronization
Advanced Micro Devices, Inc.	Accelerating Zero Knowledge Proofs on Multithreaded AMD CPUs
Analog Devices, Inc.	Development of system identification tools for precise control of motors
LLNL	Non-Intrusive Parallel-in-Time Solvers for Partial Differential Equations
NASA Ames	Classical Simulation of Non-Clifford Noise Channels in Stabilizer Formalism
NASA Goddard	Testing and Enhancement of Machine Learning Parameterizations in a Cloud-Based Environment
RAND	Deep Generative Approaches to Network Science for Social System Simulations
Relay Therapeutics	Comparing Approaches to Generative Molecular Design in Early Drug Discovery
SimCorp	Private Equity Fund Risk Modelling

Aerospace Corp

Project Title: Optimal Diffusion Kalman Filter for Lunar Time Synchronization

Project Description: There has been an increasing eye towards developing a Lunar Time Estimation (LTE) system for use in a future Lunar Surface Communication Network (LSCN),

with NASA, Aerospace and Nokia among a range of interested organizations. A reliable LSCN will require accurate, precise, and synchronized time estimates across a network of Lunar base stations. Bhamidipati et al. (2022) ∗ propose a modified Diffusion Kalman Filter for Lunar timing, which uses intermittently available Earth-GPS signals and measurements from neighboring stations to maintain accurate, synchronized time estimates. In this report, we first outline our implementation of the Diffusion Kalman Filter proposed by Bhamidipati et al. Secondly, we explore optimizing our filter over the network weights used for diffusion to approach the error of a centralized estimate, which is optimal in the minimum mean squared error (MMSE) sense. We evaluate and compare the performance of a range of cost functions and optimization techniques, with applications to optimization on generalized diffusion algorithms. We also translate some results of the classical Diffusion Kalman Filter outlined by Cattivelli Sayed (2010) † to our LTE Diffusion Filter, most notably deriving the bias of our filter's estimate. Our effort more broadly aligns with renewed interest in Lunar missions and developing a sustainable human presence on the Moon.

Advanced Micro Devices, Inc. (AMD)

Project Title: Accelerating Zero Knowledge Proofs on Multithreaded AMD CPUs
Project Description: Zero-knowledge proofs allow one to demonstrate the truth of a statement without disclosing any information other than the fact that the statement is true. Real-world applications of these proofs can be found in authentication protocols, privacy-preserving data exchange, secure multi-party computation, and blockchain. The goal of this project is to accelerate zero-knowledge proof algorithms on Advanced Micro Devices, Inc. (AMD) central processing units and benchmark them against existing implementations. We propose two methods for optimizing these algorithms: 1) parallelized Montgomery multiplication as part of the proving process and 2) fast hashing and pairings as part of the verification process. Accelerating zero-knowledge proofs on AMD CPUs allows the company to use its hardware for state-of-the-art cryptographic methods efficiently.

Analog Devices, Inc.

Project Title: Development of system identification tools for precise control of motors
Project Description: Motor control is incredibly important in various applications, ranging from robotics to the automobile industry. Ensuring precision and accuracy of motors requires accurate system identification tools. System identification is the process of modelling the transfer function, which characterizes the dynamic behavior of a system and its response to input signals. The Vector Fitting (VF) Algorithm, an algorithm that iteratively adjusts the poles and residues of an approximated transfer function, is a prominent technique used in this regard, known to work well with exact data. However, when data is noisy, as is often the case in practical scenarios, VF runs into convergence and poor prediction issues. To address the prediction issues, we explore the use of neural networks as an alternative approach for approximating the target transfer function. Specifically, we investigate two types of neural networks: the widely used ReLU neural network and a rational neural network, which uses rational functions as a non-linear activation function. The motivation for using two different architectures is to compare the performance of a standard and a more complex activation function in handling noise in the data. We run numerical experiments to verify the effectiveness of these neural network models in approximating transfer functions. Our results show that the rational neural network provides a powerful tool for analyzing and reconstructing the transfer function mathematically, which is not

possible with a standard deep neural network. Additionally, the rational neural network has fewer parameters to train and achieves similar or higher accuracy scores to the ReLU deep neural network, despite being mathematically less complex. This combination of interpretability and efficiency makes the rational neural network a possible candidate for future studies on system identification tools.

Lawrence Livermore National Laboratory (LLNL)

Project Title: Non-Intrusive Parallel-in-Time Solvers for Partial Differential Equations
Project Description: Many time-dependent problems and simulations are often modeled using Partial Differential Equations. Traditional modeling approaches that use sequential time-stepping are reaching a bottleneck in optimizing efficiency. The Center of Applied Science and Computing at Lawrence Livermore National Laboratory extensively works on parallelizing these algorithms to leverage the increasing computational power from the growing number of processors in computer hardware. In particular, they aim to design non-intrusive algorithms that can generalize to a variety of problems and sizes without requiring additional information from or modifications on the original problems. Multigrid Reduction in Time (MGRIT) is a parallel-in-time algorithm that is designed to be non-intrusive. This project focuses on increasing the efficiency of MGRIT by approximating the coarse-grid operator using machine learning approaches as a means to find the most non-intrusive, or general, solution.

NASA Ames

Project Title: Classical Simulation of Non-Clifford Noise Channels in Stabilizer Formalism
Project Description: We introduce the basics of quantum computing and simulation of quantum systems on classical computers. We then discuss noise in quantum systems and how it is classically modelled, along with the difficulties of simulating quantum noise on classical computers. Our primary question is how to efficiently simulate quantum noise by leveraging existing techniques based upon the Gottesman-Knill theorem, which provides efficient simulation of circuits containing only Clifford gates. We follow this by describing our progress thus far in exploring three primary approaches. First, exploring methods to decompose a noise operator into a sum of cliffords via mixed integer linear programming and using these decompositions to classically simulate noisy quantum circuits within the stabilizer formalism first proposed by Aaronson and Gottesman (2004). We find that the a Clifford decomposition is not guaranteed to have low rank decompositions and that at best the runtime of simulating noise using Clifford decompositions would be O(2k), where k is the number of Kraus operators applied. Second, we explore the process of dilating our space to convert our noise operators into unitaries in a larger space. Specifically, we propose two unitary dilation based algorithms for simulating noise; Sz.-Nagy and Stinespring's dilation algorithms. The two algorithms yield respective run-times of $O(\frac{1}{\delta\Delta^2} s n^3 \eta^{-2} 1.17^t)$ and $O(n^2 \prod_{i=1}^{k} |\xi_i| + n^3 \sum_{i=1}^{k} |\xi_i|^3)$. Third we propose a theoretical framework for generalizing the T-Gadget approach developed by Bravyi and Gosset (2016). Through numerical simulations we show that the generalized framework can be used to produce noise simulation algorithms with efficient runtime and space complexity.

NASA Goddard

Project Title: Testing and Enhancement of Machine Learning Parameterizations in a Cloud-Based Environment

Project Description: Global Climate Models are pivotal for predicting and understanding Earth's climate system. In particular, variability in vertical wind velocities are critical to weather forecasting. Existing predictive models include an artificial neural network (ANN) trained on simulated data nested within a conditional generative adversarial network (cGAN) that improves predictions based on observational data. To test these models, we employ a variety of evaluative and comparative metrics, including pointwise error metrics like Mean Squared Error (MSE), correlation scores like Normalized Cross Correlation (NCC), and distance metrics like Kolmogorov Smirnov (KS) statistic and Earth Mover's Distance (EMD). Furthermore, we assess and tune the model training architecture through hyperparameter sensitivity analysis and customization of the loss and activation functions. Finally, we generate confidence intervals to provide a range of certainty for our model predictions. On top of that, we propose potential model enhancements, such as integrating ensemble methods to better adapt to elevation-dependent atmospheric dynamics.

RAND

Project Title: Deep Generative Approaches to Network Science for Social System Simulations
Project Description: Microsimulation and agent-based models are increasingly being used to simulate complex social systems and to understand everyday interaction networks. However, accurate microsimulation models require comprehensive network data sets that combine large-scale network structures with detailed individual-level behavioral characteristics. Integrating diverse network data sources to produce accurate simulation models of complex social phenomena is a challenging task with limited research. Our project focuses on two main objectives:

1. Generate synthetic networks that are statistically and structurally equivalent to an existing sociocentric network dataset from Portland, Oregon. We used the Iterative Local Expansion method to achieve a scalable machine learning model for graph generation.

2. Perform network fusion by combining the synthetically generated dataset with egocentric network survey data to create a comprehensive social network. To achieve this goal, we developed a mathematical algorithm that accounts for egocentric node features and models the time-dependent behavior of the sociocentric network through node interactions.

The ultimate aim of this project is to further researcher's ability to generative complex and comprehensive graph network datasets for populations of interest for the purpose of improving social simulations like those in disease transmission.

Relay Therapeutics

Project Title: Comparing Approaches to Generative Molecular Design in Early Drug Discovery
Project Description: In recent years, Generative Artificial Intelligence (AI) models have demonstrated promising advancements in the acceleration of drug discovery. Despite their growing popularity, there has been little work done to compare existing models or to establish a quantitative framework for their validation. The aim of this project is to rigorously characterize the differences in performance and behavior of different models using both qualitative insights

and quantitative metrics. To do so, we perform an in-depth exploration of four popular text-SMILES based models across a variety of tasks. Furthermore, we develop several methods to effectively differentiate between generative models; a random forest pipeline for classifying molecules and producing meaningful low-dimensional visualizations, a comparative analysis of models' performance in a hit-to-lead optimization setting, and a large-scale study of the distributions of molecules generated from each model, focusing on information like structural diversity and protein-ligand interactions. In doing so, we also highlight several limitations of current "state-of-the-art" models. Finally, we propose a new metric, sensitivity, which captures information regarding the variance in the properties of a generated distribution of molecules with respect to the corresponding input fragment. We hope that this work will contribute to the development of a universal benchmark to compare new and existing generative AI models for molecular drug-design.

SimCorp

Project Title: Private Equity Fund Risk Modelling

Project Description: This report presents a comprehensive analysis of risk modeling in private equity funds, driven by the increasing complexity and significance of these investment vehicles in today's financial landscape. Our research aims to address the critical challenges faced by investors in both public and private markets. We begin by defining key concepts such as public markets, private markets, and the characteristics of private equity funds. The proposed problem centers on the inherent risks associated with private equity investments, which can significantly impact returns. To tackle this issue, our team implemented a robust algorithmic approach that leverages advanced statistical methods, including Markov Chain Monte Carlo (MCMC) techniques for parameter estimation and risk quantification. The methodology encompasses hierarchical sampling strategies for model parameters, ensuring a comprehensive assessment of risk factors. Synthetic data generation plays a pivotal role in our analysis, allowing us to simulate market conditions and produce realistic cash flow scenarios for various funds. We meticulously evaluate our model through extensive parameter tuning and validation against control datasets. The results highlight key insights into the algorithm's ability to detect noise and its sensitivity to initialization, underpinning the importance of precise risk modeling for informed investment decisions. Key processes involve creating a private market return index using the Fama/French Three Factor Model, simulating quarterly compounded returns, and modeling fund creation and cash flow behaviors. The MCMC algorithm was rigorously tested on these synthetic datasets to assess its performance.

STUDENT RESEARCH PROGRAM

Research in Industrial Projects for Students (RIPS), Singapore

May 20 - July 19, 2024

The Los Angeles program is complemented by a satellite program in Singapore. Similar to the Los Angeles program, RIPS provides an opportunity for talented undergraduates studying math, computer science, and related disciplines to work in teams on a real-world research project proposed by sponsors from industry or the public sector. The student team, with support from their academic mentor and industry mentor, will research the problem and present their results, both orally and in writing, at the end of the program. The REU program is nine weeks. IPAM provides each undergraduate student with a stipend of $4,200.

Round-trip travel and accommodations costs are covered by IPAM. Students also receive a meal allowance and a stipend, and conference support to present their research. These terms apply to U.S. participants recruited by IPAM. A total of 4 students participated in the RIPS Singapore program.

2024 INDUSTRY PARTNERS	PROJECT TITLES
Cubist Systematic Strategies	Retrieval-Augmented Generation on SEC 10Q & 10K Filings
Ministry of Health Office for Healthcare Transformation (MOHT)	Automated Qualitative Thematic Analysis of Posts on Let's Talk
Proctor & Gamble	Adaptive Bayesian Methodologies for Trial Optimization Using Historical Data
Qube Research Technologies	Prediction of Cryptocurrency Price Movements Based on Twitter Sentiment and Volume Data

Cubist Systematic Strategies

Project Title: Retrieval-Augmented Generation on SEC 10Q & 10K Filings
Project Description: Manually processing financial documents such as SEC 10K and 10Q filings is a time-consuming task in the financial sector. The introduction of Large Language Models (LLMs) provides a promising method for expediting this process. However, LLMs face issues, such as hallucination, when faced with domain-specific tasks. A common strategy to combat this is the use of Retrieval Augmented Generation (RAG). This is an architecture that creates a knowledge base from a corpus of text which can be searched to provide an LLM with additional information to answer a query. We perform a literature review on RAG with a focus on its applications to the financial sector, develop a prototype Question-Answering (QA) system to demonstrate the potential for RAG to be used in the financial sector, and perform benchmarking on various techniques from our literature review.

MOHT

Project Title: Automated Qualitative Thematic Analysis of Posts on Let's Talk
Project Description: The goal of this project is to understand the users and discussions from Let's Talk, the mental health forum established by the Ministry of Health Office of Transformation (MOHT), and to build a pipeline that automatically generates an analytic report of the users and posts on a regular basis. The analysis performed includes topic modeling of Let's Talk forum posts using unsupervised clustering, user engagement analysis across topics, and time series analysis of forum posts. Based on the analysis, a BERTopic clustering pipeline for automatic generation of forum tags is implemented accordingly. We propose a method to perform meta-clustering on topic representations from BERTopic clustering algorithm in order to account for the stochastic component of UMAP dimensionality reduction. In our approach, we employ non-negative matrix factorization (NMF) to automatically measure similarities between different topic representations in order to perform clustering. This approach was combined with a GPT-4 based topic classification procedure into a pipeline for forum post classification and analysis report generation. Finally, a comparison between Let's Talk, Reddit mental health

sub-reddits, and HardWareZone forum posts was performed to identify similarities and differences in topics that users from different platforms and potentially different demographics discuss.

Procter & Gamble

Project Title: Adaptive Bayesian Methodologies for Trial Optimization Using Historical Data
Project Description: Our collaborative project with Procter & Gamble (P&G) explores the application of Bayesian
Dynamic Borrowing (BDB) methodologies to optimize Randomized Controlled Trials (RCTs) in oral care and face cream datasets using historical data integration. The primary aim is to reduce sample size requirements for control groups while maintaining statistical rigor. We focus on developing adaptive strategies that incorporate historical data into current trials, thereby enhancing efficiency and accelerating decision-making in clinical studies.

We evaluate various BDB techniques such as power priors, commensurate priors, Elastic Priors, Bayesian hierarchical models, and meta-analytic-predictive priors. Through simulations and analysis, we assess these methods' performance in oral care and face cream datasets, particularly examining bias, variance, and statistical power across different scenarios of treatment and historical data alignment.

Initial findings suggest that methods like the power prior and commensurate prior effectively control bias, while the Elastic Prior provides a balanced approach considering bias, variance, and computational efficiency, especially in scenarios of partial congruence between historical and current trial data.

Furthermore, we demonstrate the application of these methodologies through sample analyses, such as varying the means of treatment and control groups, and historical versus control groups, exploring the impact of individual noise, and assessing how historical data influences treatment distributions in a Round-robin model. This research not only highlights the practical advantages of advanced Bayesian techniques in oral care and cosmetic product trials but also contributes to advancing statistical methodology in clinical trial design and analysis.

Qube Research Technologies

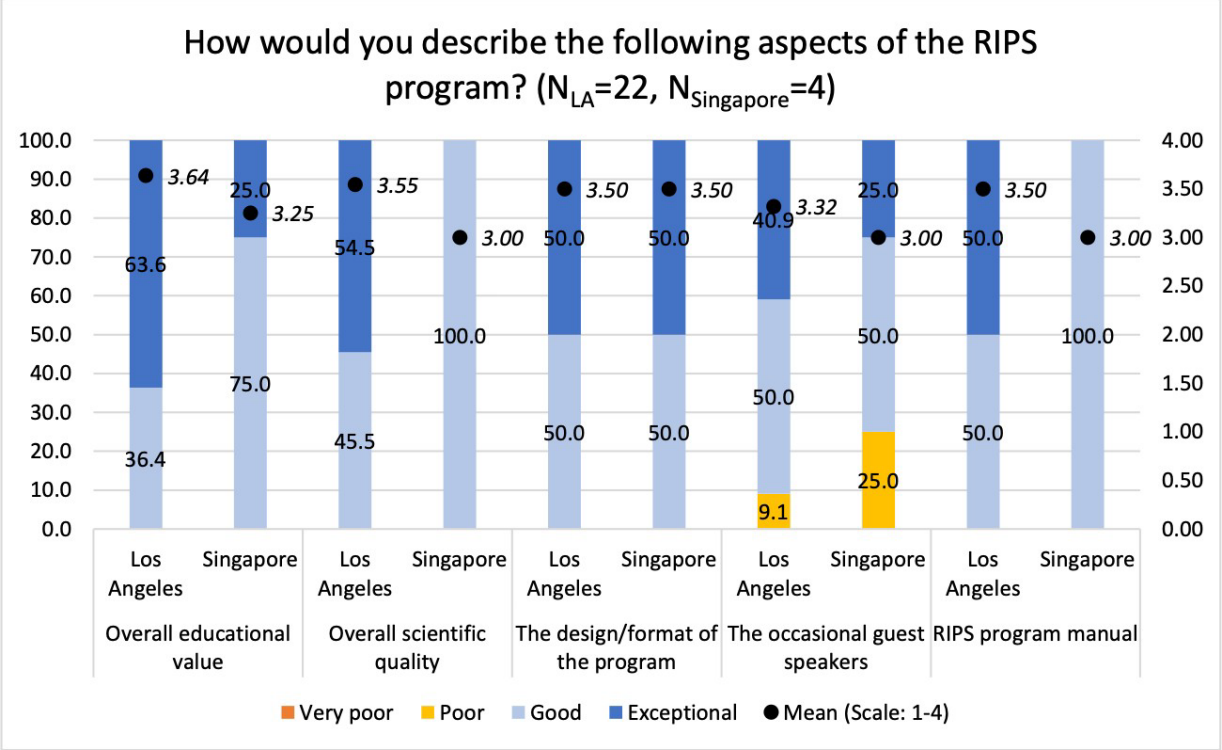
Project Title: Prediction of Cryptocurrency Price Movements Based on Twitter Sentiment and Volume Data
Project Descriptions: This report investigates the prediction of cryptocurrency price movements by analyzing Twitter sentiment and transaction volume data. We leveraged minute-by-minute price data for 43 cryptocurrencies, sentiment scores from 15 models provided by the company, and transaction volume data from the Binance website. The study primarily focuses on several cryptocurrencies with extensive sentiment and price data availability. Through comprehensive exploratory data analysis (EDA), we identified a locally linear correlation among sentiment scores, volume, and price changes. We also developed a profit calculation mechanism, employing a streamlined trading strategy that evaluates model performance using metrics such as cumulative profit and Sharpe ratio.

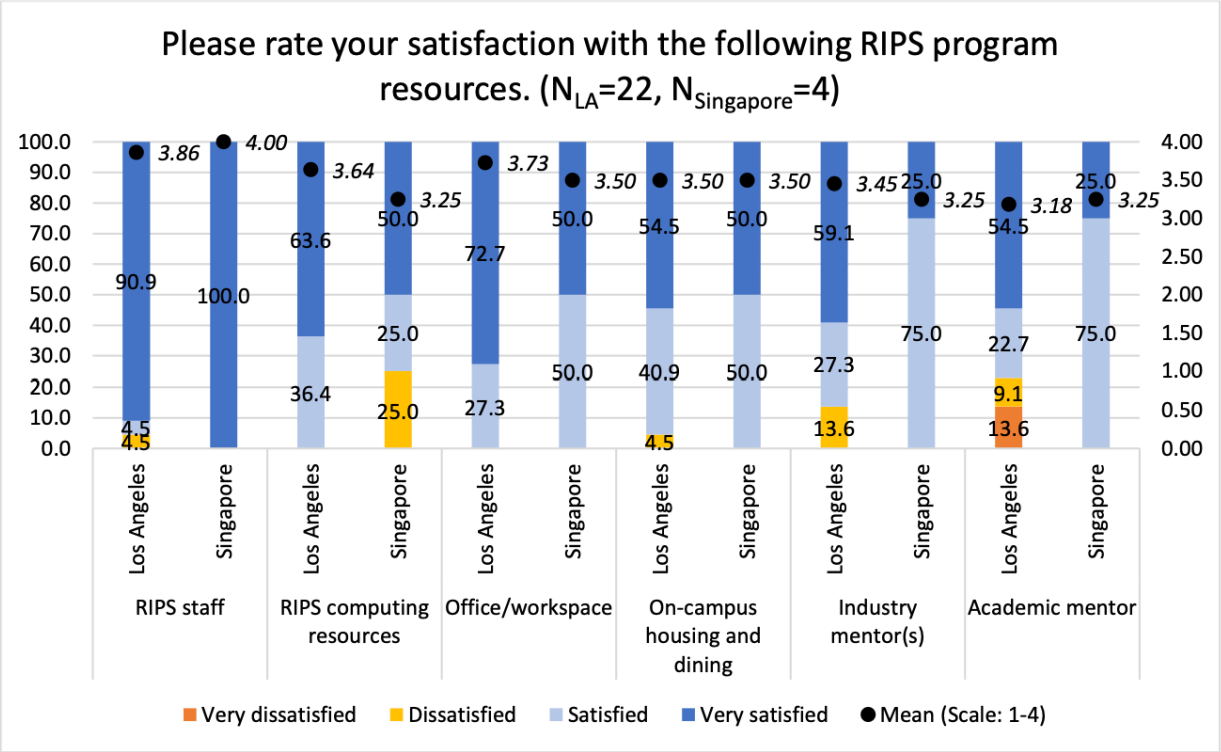
We developed and evaluated various predictive models. Chunked Linear Regression provided

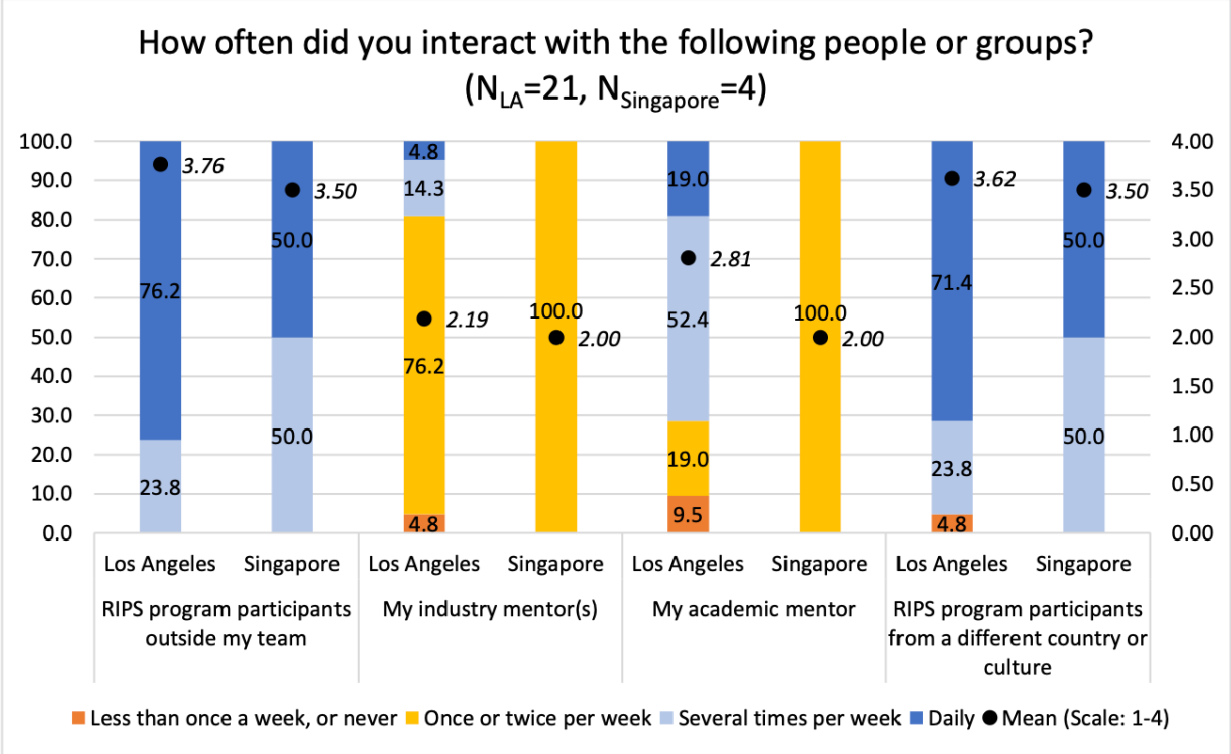
the most accurate predictions, benefiting from smaller prediction intervals and the application of a Gaussian filter for feature smoothing. While Random Forest (RF) and Multilayer Perceptron (MLP) generated profits comparable to Chunked Linear Regression, they exhibited less stability due to the complexity of their hyperparameters. In contrast, Convolutional Neural Network (CNN) and S4D models underperformed, possibly due to data reshaping processes that might have disrupted critical information. This area will be addressed in future studies. These findings underscore the significance of feature engineering, model selection, and hyperparameter tuning in enhancing prediction accuracy.

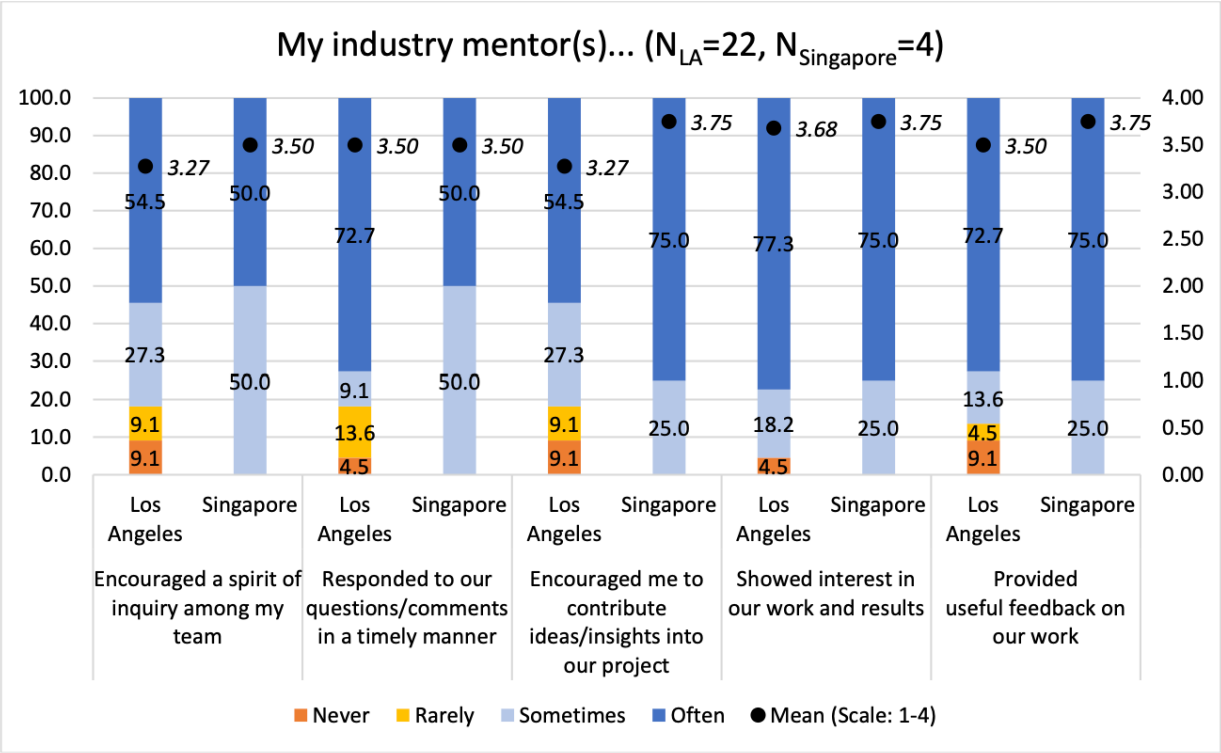
RIPS 2024 Participant Survey Results

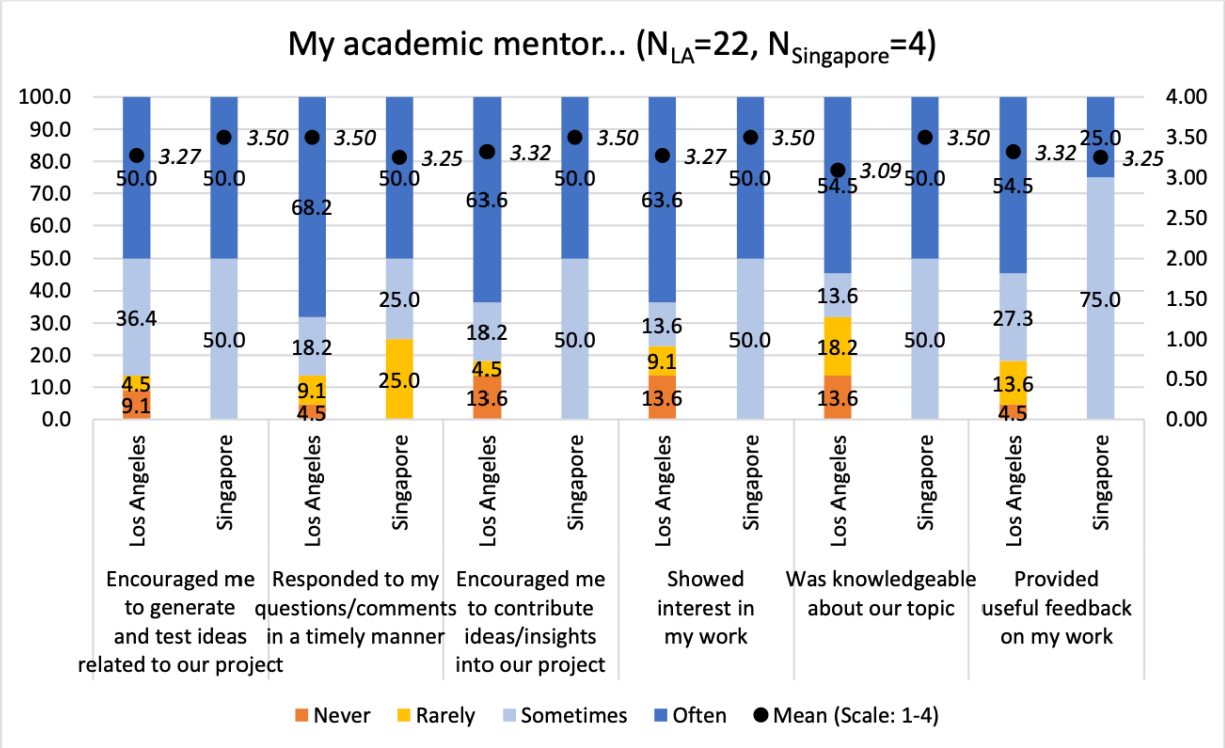
IPAM surveys RIPS participants (both LA and Singapore) both pre- and post-participation. They surveys are designed to elicit feedback from participants as well as to gauge the effectiveness of the program. A total of 39 Los Angeles and Singapore RIPS participants responded to surveys (35 pre-program, 26 post-program), with 22 completing both the pre- and post-program surveys. Chart data are disaggregated by campus and summarize their respective response frequencies and mean response scores.

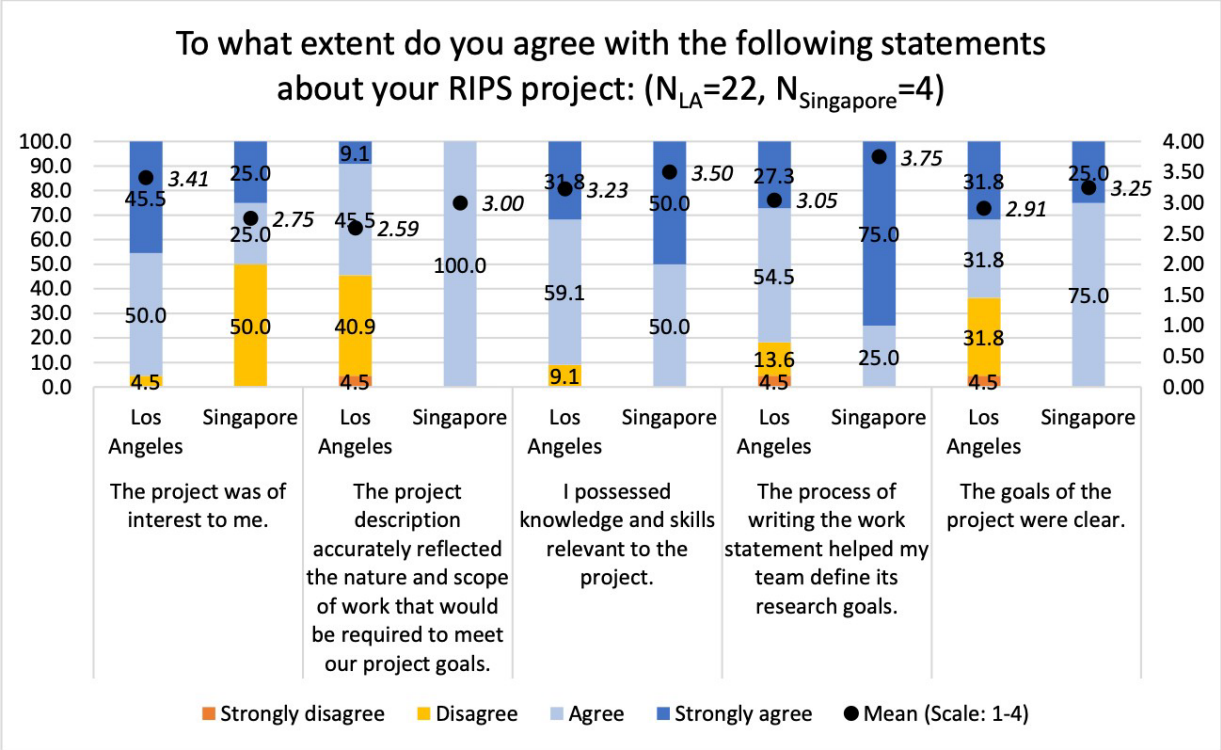


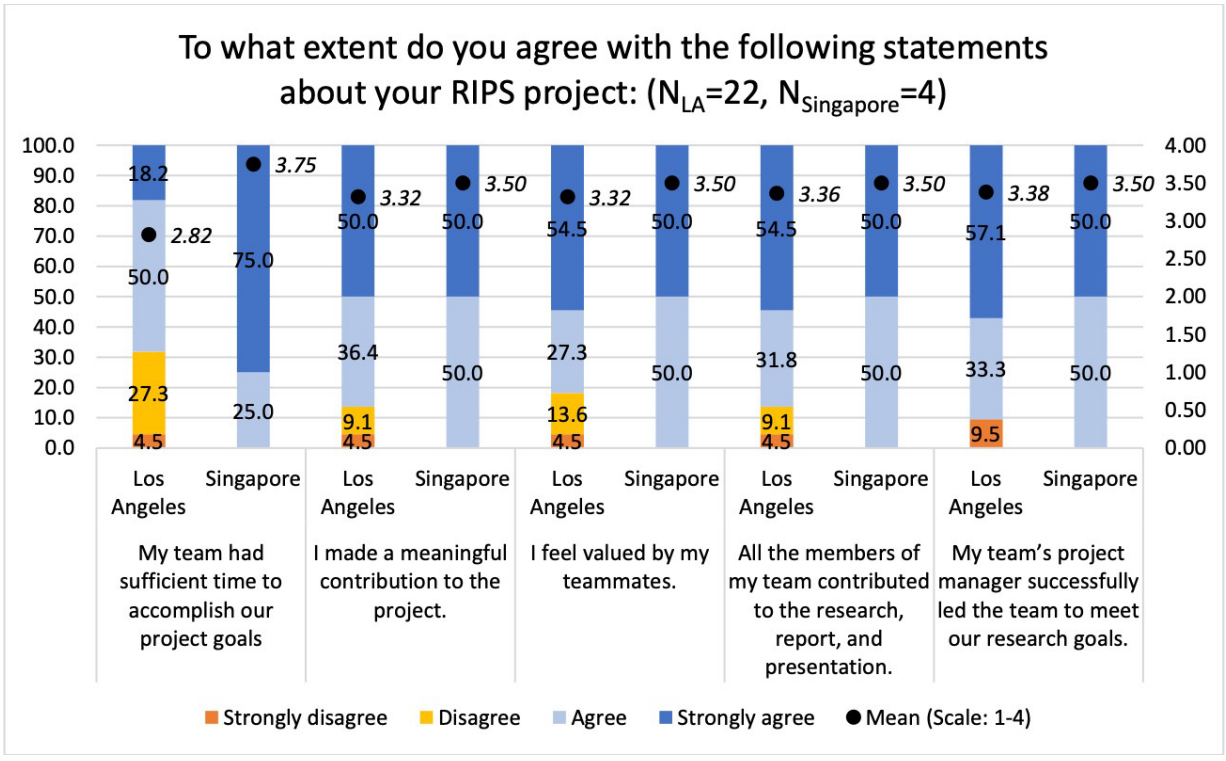

Please rate your satisfaction with the following RIPS program resources. (N_{LA}=22, $N_{Singapore}$=4)
RIPS staff
RIPS computing resources
Office/workspace
On-campus housing and dining
Industry mentor(s)
Academic mentor
Los Angeles
Singapore
Very dissatisfied
Dissatisfied
Satisfied
Very satisfied
Mean (Scale: 1-4)

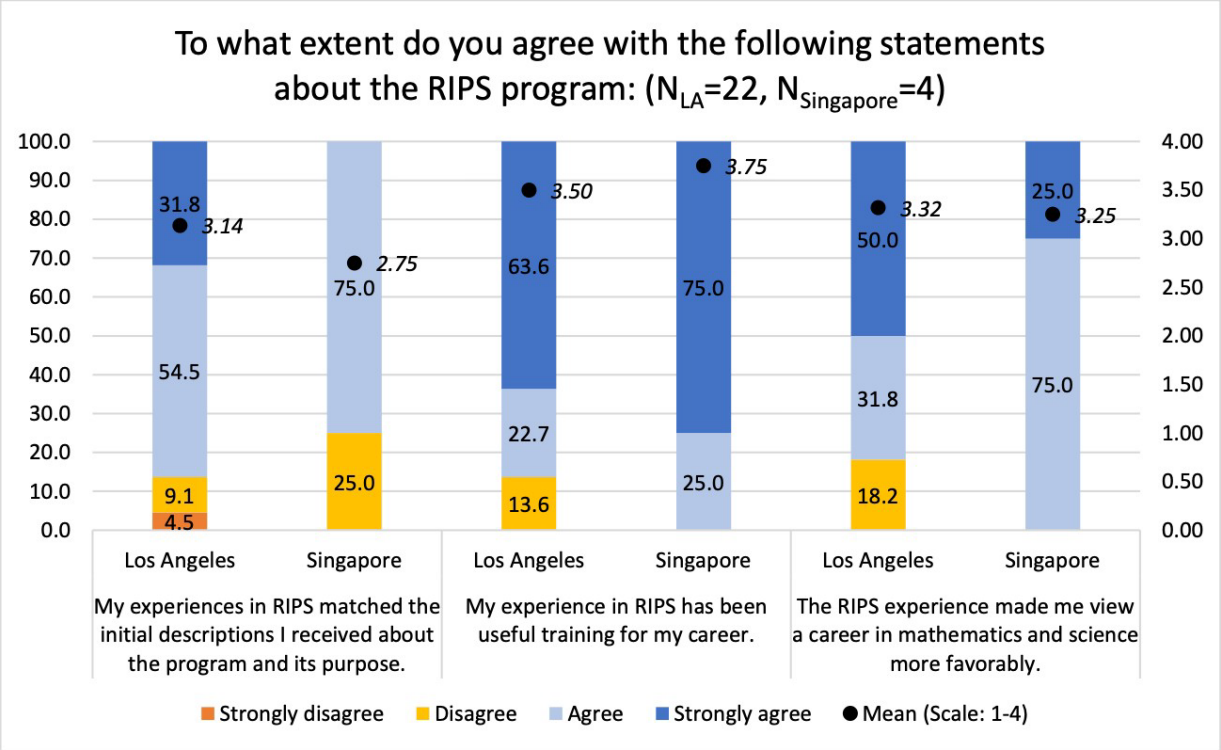

How often did you interact with the following people or groups? (N_{LA}=21, $N_{Singapore}$=4)
RIPS program participants outside my team
My industry mentor(s)
My academic mentor
RIPS program participants from a different country or culture
Los Angeles
Singapore
Less than once a week, or never
Once or twice per week
Several times per week
Daily
Mean (Scale: 1-4)

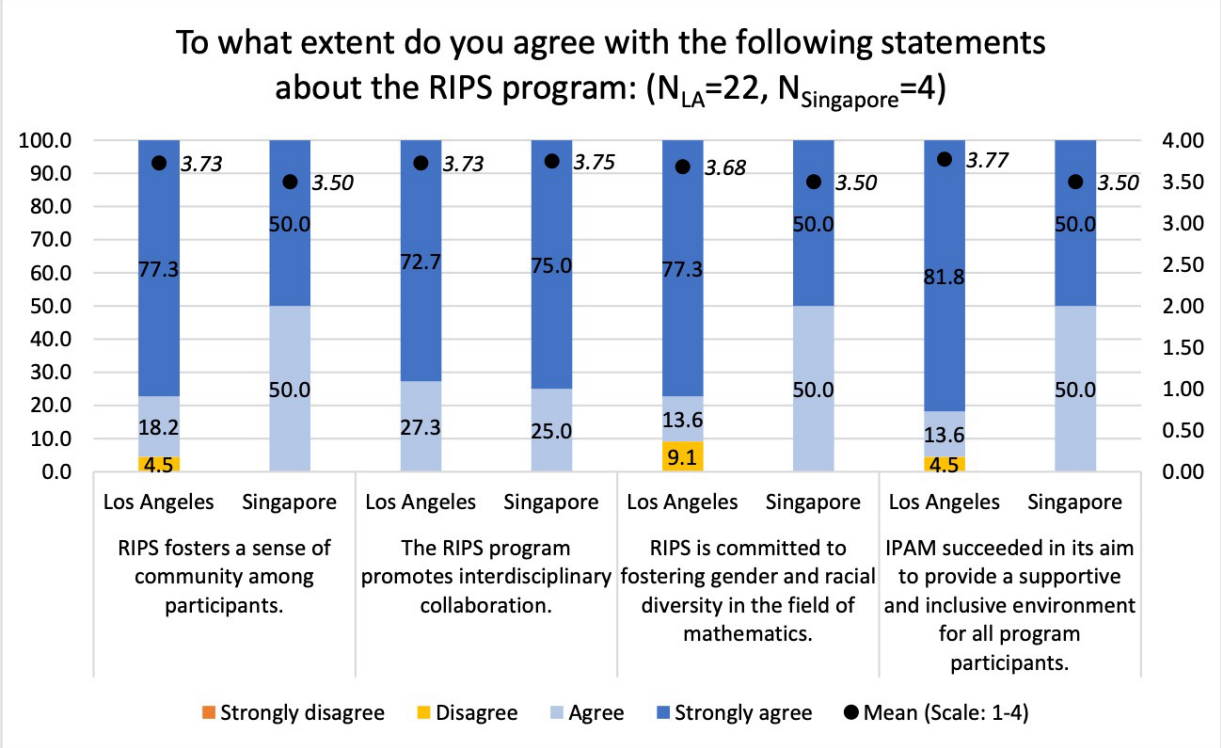

My industry mentor(s)... (N_{LA}=22, $N_{Singapore}$=4)
Encouraged a spirit of inquiry among my team
Responded to our questions/comments in a timely manner
Encouraged me to contribute ideas/insights into our project
Showed interest in our work and results
Provided useful feedback on our work
Los Angeles
Singapore
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)

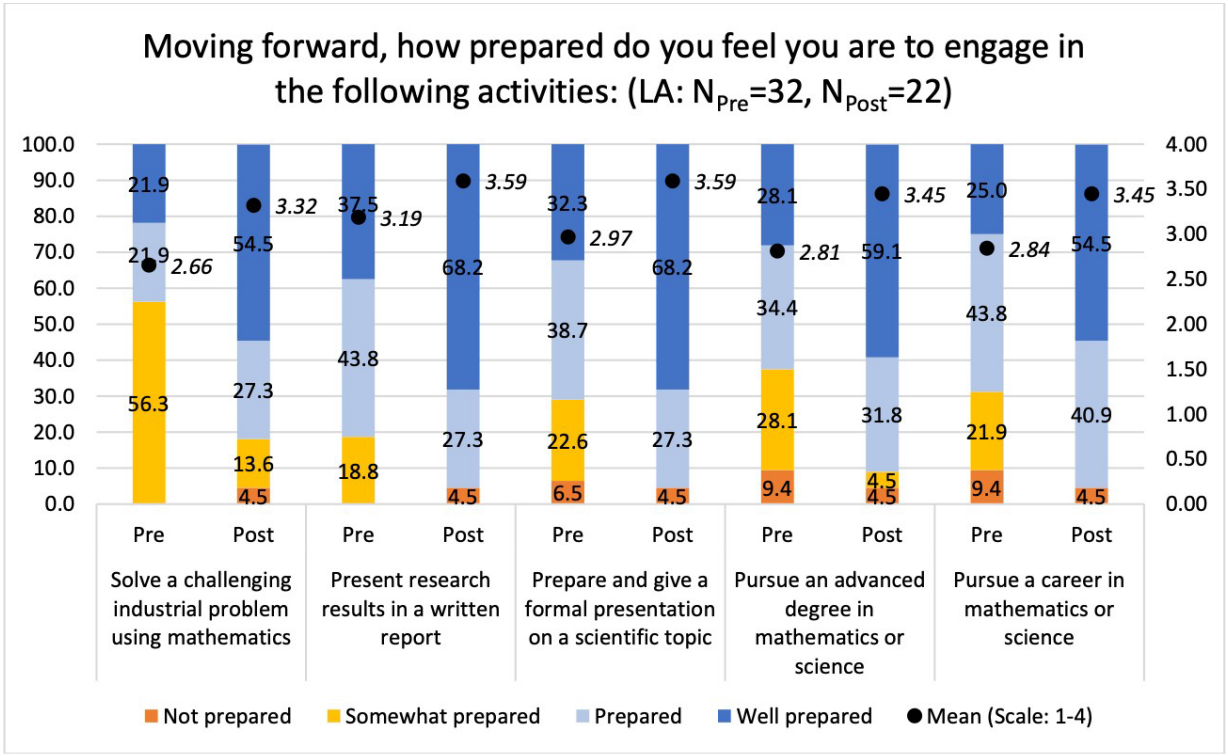

My academic mentor... (N_{LA}=22, $N_{Singapore}$=4)
Encouraged me to generate and test ideas related to our project
Responded to my questions/comments in a timely manner
Encouraged me to contribute ideas/insights into our project
Showed interest in my work
Was knowledgeable about our topic
Provided useful feedback on my work
Los Angeles
Singapore
Never
Rarely
Sometimes
Often
Mean (Scale: 1-4)

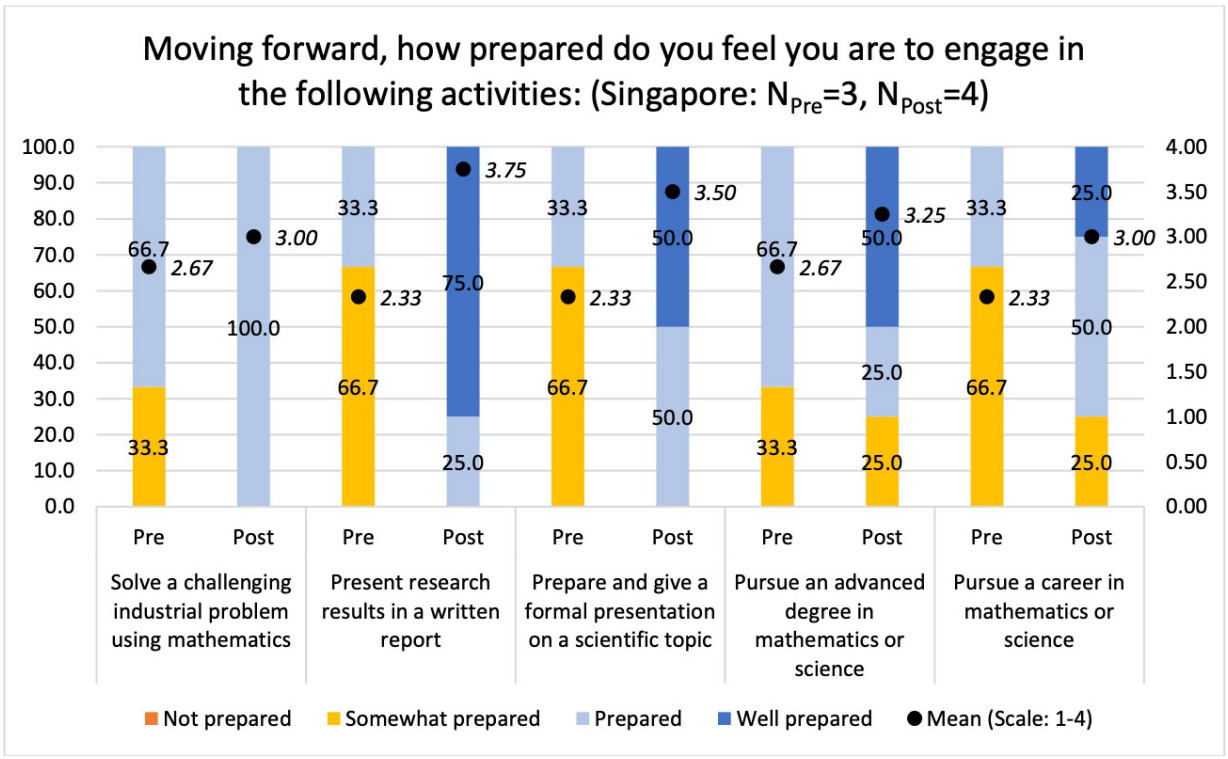

To what extent do you agree with the following statements about your RIPS project: (N_{LA}=22, $N_{Singapore}$=4)
100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0
4.00 3.50 3.00 2.50 2.00 1.50 1.00 0.50 0.00
45.5 50.0 4.5 3.41
25.0 50.0 25.0 2.75
9.1 45.5 40.9 4.5 2.59
100.0 3.00
31.8 59.1 9.1 3.23
50.0 50.0 3.50
27.3 54.5 13.6 4.5 3.05
75.0 25.0 3.75
31.8 31.8 4.5 2.91
25.0 75.0 3.25
Los Angeles
Singapore
The project was of interest to me.
The project description accurately reflected the nature and scope of work that would be required to meet our project goals.
I possessed knowledge and skills relevant to the project.
The process of writing the work statement helped my team define its research goals.
The goals of the project were clear.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)

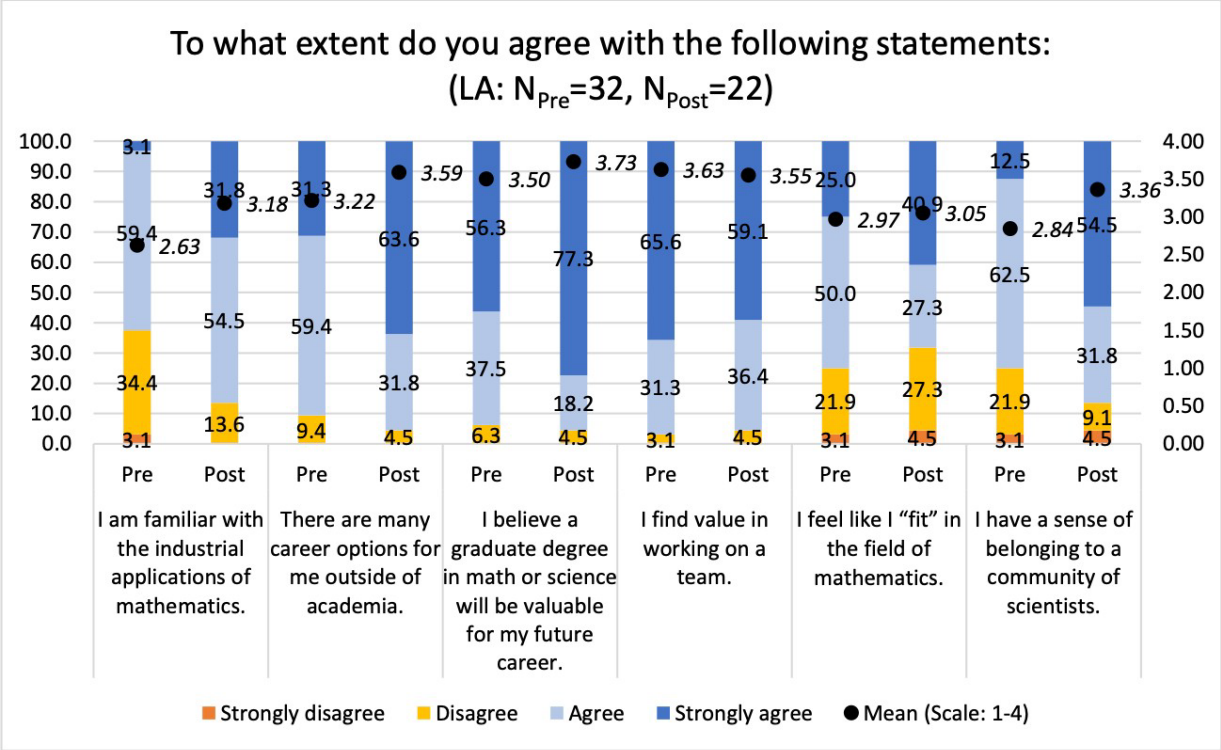

To what extent do you agree with the following statements about your RIPS project: (N_{LA}=22, $N_{Singapore}$=4)
100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0
4.00 3.50 3.00 2.50 2.00 1.50 1.00 0.50 0.00
18.2 50.0 27.3 4.5 2.82
75.0 25.0 3.75
50.0 36.4 9.1 4.5 3.32
50.0 50.0 3.50
54.5 27.3 13.6 4.5 3.32
50.0 50.0 3.50
54.5 31.8 9.1 4.5 3.36
50.0 50.0 3.50
57.1 33.3 9.5 3.38
50.0 50.0 3.50
Los Angeles
Singapore
My team had sufficient time to accomplish our project goals
I made a meaningful contribution to the project.
I feel valued by my teammates.
All the members of my team contributed to the research, report, and presentation.
My team's project manager successfully led the team to meet our research goals.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)

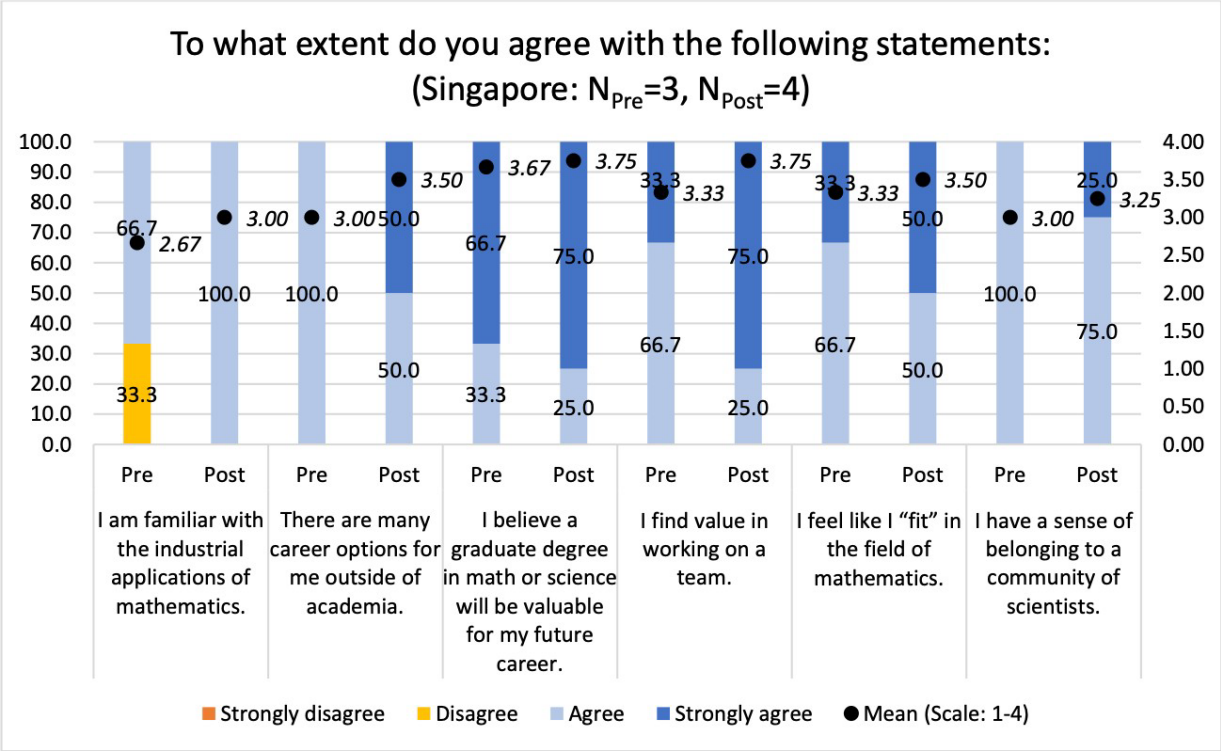

To what extent do you agree with the following statements about the RIPS program: (N_{LA}=22, $N_{Singapore}$=4)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
31.8
3.14
54.5
9.1
4.5
2.75
75.0
25.0
3.50
63.6
22.7
13.6
3.75
75.0
25.0
3.32
50.0
31.8
18.2
25.0
3.25
75.0
Los Angeles
Singapore
My experiences in RIPS matched the initial descriptions I received about the program and its purpose.
My experience in RIPS has been useful training for my career.
The RIPS experience made me view a career in mathematics and science more favorably.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)

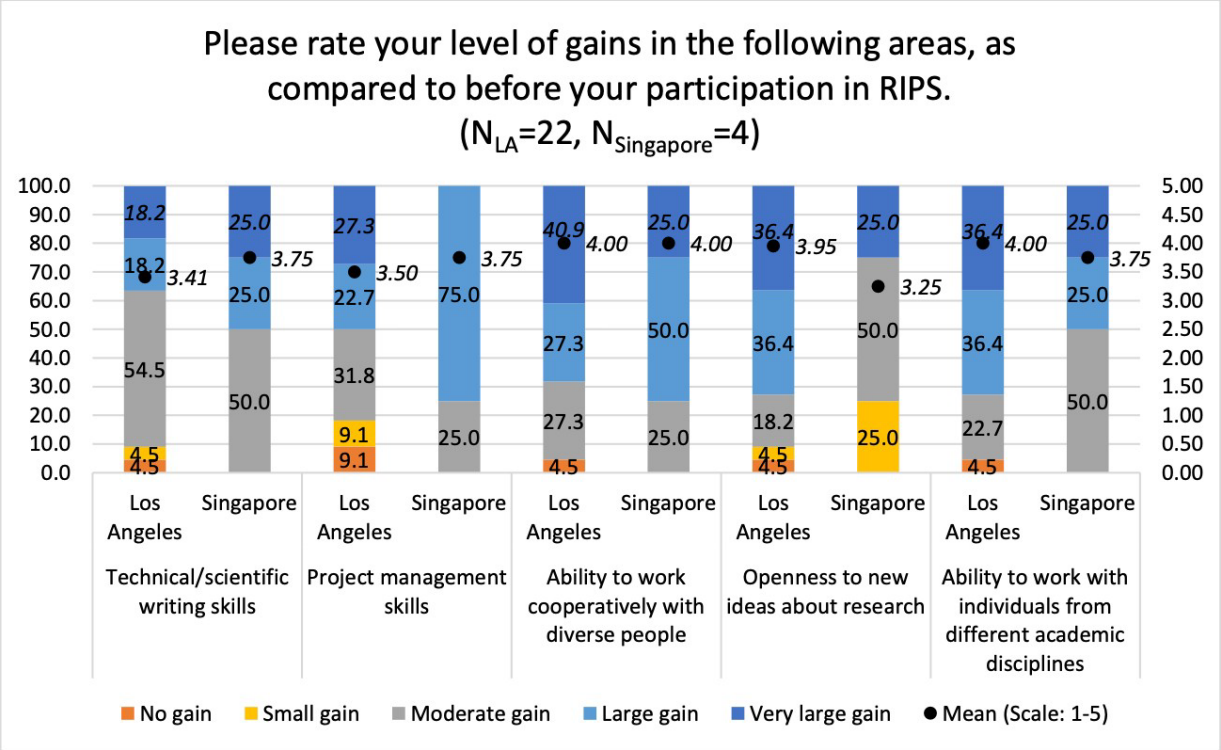

To what extent do you agree with the following statements about the RIPS program: (N_{LA}=22, $N_{Singapore}$=4)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
3.73
77.3
18.2
4.5
3.50
50.0
50.0
3.73
72.7
27.3
3.75
75.0
25.0
3.68
77.3
13.6
9.1
3.50
50.0
50.0
3.77
81.8
13.6
4.5
3.50
50.0
50.0
Los Angeles
Singapore
RIPS fosters a sense of community among participants.
The RIPS program promotes interdisciplinary collaboration.
RIPS is committed to fostering gender and racial diversity in the field of mathematics.
IPAM succeeded in its aim to provide a supportive and inclusive environment for all program participants.
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


Moving forward, how prepared do you feel you are to engage in the following activities: (LA: N_Pre=32, N_Post=22)
Pre
Post
Solve a challenging industrial problem using mathematics
Present research results in a written report
Prepare and give a formal presentation on a scientific topic
Pursue an advanced degree in mathematics or science
Pursue a career in mathematics or science
Not prepared
Somewhat prepared
Prepared
Well prepared
Mean (Scale: 1-4)


Moving forward, how prepared do you feel you are to engage in the following activities: (Singapore: N_Pre=3, N_Post=4)
Pre
Post
Solve a challenging industrial problem using mathematics
Present research results in a written report
Prepare and give a formal presentation on a scientific topic
Pursue an advanced degree in mathematics or science
Pursue a career in mathematics or science
Not prepared
Somewhat prepared
Prepared
Well prepared
Mean (Scale: 1-4)


To what extent do you agree with the following statements:
(LA: N_Pre=32, N_Post=22)
I am familiar with the industrial applications of mathematics.
There are many career options for me outside of academia.
I believe a graduate degree in math or science will be valuable for my future career.
I find value in working on a team.
I feel like I "fit" in the field of mathematics.
I have a sense of belonging to a community of scientists.
Pre
Post
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)


To what extent do you agree with the following statements:
(Singapore: N_Pre=3, N_Post=4)
I am familiar with the industrial applications of mathematics.
There are many career options for me outside of academia.
I believe a graduate degree in math or science will be valuable for my future career.
I find value in working on a team.
I feel like I "fit" in the field of mathematics.
I have a sense of belonging to a community of scientists.
Pre
Post
Strongly disagree
Disagree
Agree
Strongly agree
Mean (Scale: 1-4)



The surveys rated the Los Angeles program very highly. Both Los Angeles and Singapore programs have shown significant positive impact on student attitudes towards viewing mathematics as a viable career path (in and out of academia), and their desire to obtain an advanced degree. We are working with our Singapore partners to address student feedback related to ensuring a supportive an inclusive environment, as well as providing good academic mentorship. The RIPS Director visited Singapore (including coming for the 2024 opening day) to discuss these issues.

Student comments:

- I don't really believe this is a math program and I think that should be more clear on the website. I applied on mathprograms.com, it is called Institute of Pure and Applied Math and I talked on Zoom with a math professor before coming here but I received zero math mentorship and my team members were not very knowledgeable about math anyway, they were more knowledgeable about engineering so I felt isolated.
- I enjoyed the whole program and I am very thankful to the Selections committee to give me… a chance to come to US and work with an amazing team on an amazing project in an amazing environment.
- I really loved RIPS, it was my first research experience, and I got pretty satisfied with the outcome of the project and the friendships I made. Some of the strong points this program has are: -Getting to know people from many international and different cultural contexts: This is one of the core that makes RIPS the program it is. -Meeting with very talented people that share a passion for mathematics and science in general: I think I'll never meet the kind of people that I met at RIPS, they eat, breathe and love math. I ended up loving

the kind of funny conversations and jokes about math topics. -Provide the accommodation and flights for the team's sponsor site visit: When I was informed about we were going to flight to visit our sponsor, I couldn't believe it, that was such an amazing experience and opportunities for students to travel and know a new city. -Give the opportunity to present a poster or give a talk in a national conference. -Promote activities to engage as a group (ex. RIPS Talent Show, Zumba session, Hiking to Temescal Canyon) -Work in a team setting where each member complement each other. -Getting a graduation and yearbook: Having a yearbook for this RIPS edition was such a nice gift from this program. As it is stated, RIPS promises to be a mix of an REU and Internship (That was an excellent hybrid for me!), nevertheless, some students that haven't had any industry experience can get disappointed that you don't get to see as much math as you would in a pure REU, so maybe it is useful to emphasize a little bit more the type of program the RIPS is. Furthermore, after having our exit interview, I noticed that many teams had mixed feelings about their Academic Mentors (AM), Industry Sponsor (IS). Seeming that, getting a comprehensive AM and IS involves a luck factor (Few teams got a both good AM and IS). Therefore, some areas of improvement are: -Review the availability of the Academic mentors for RIPS: Our AM was barely present on the first half of the program. We had kind of quick lectures on the math background of the project, but we didn't receive any tips nor feedback on actual project development. By the time he was able to be full time with us (After Week 6), it was already late to keep up with the project and provide proper feedback. -Ask AM and IS specific things on the project they are: As silly as it may sound, many teams had this issue where their AM, didn't even know the project they are working on, and I think something similar happened to us. From the AMs meetings that are scheduled, we should ask AMs what is their current understanding of the project. -AM's should do 1-on-1 quick meetings with each member of the team: I think this can help to check how each member of the team is feeling about the work they are doing, and their relationship with the team, thus, if the team is not synched, the AM's should take control of the team. -Tell the IS to be patient, that RIPS teams are making new research on what they asked: We had the advantage that our sponsor was a big research institution, but for teams that are working with Tech Companies, they can be desperate and put pressure to get results as soon as possible from the team. - AM's should have the Spirit of Inquiry: We don't expect AM's to know the exact background for the project, but we should foster the collaboration in learning, between the team and it's AM. -I think it would very useful to have a Former International RIPS Student, to provide clarification on all the steps you'll have to follow to get your SSN, Submit Taxes form and Setting up your account in PaymentWorks, to get everything as soon as possible. I hope some of these comments help to improve RIPS, I like the institution a lot, and the RIPS Staff are so nice. I hope to come back some day!

- Nope, loved the program!
- One comment would be to remind admitted RIPS or GRIPS participants that you have a sense of purpose. The committee are people that look for high achieving people and all they ask is for your best.
- RIPS was by far one of the best summer programs that I have participated in. Our academic mentor was an absolute delight to work with. As industry mentors play a significant role in guiding the team, I strongly believe that more thought should be given to selecting industry mentors (based on their familiarity with the project and its

demands). The programme was fantastic and I'm grateful to everyone who made it happen. The organisation was amazing! One suggestion would be to have some additional social events organised by IPAM, such as hikes or Zumba, which would be beneficial for inter-team communication.

- We might have benefitted more from a program if the industry sponsor was more familiar with mathematics.

SUMMER SCHOOL

Groundwork for Operator Algebras Lecture Series (GOALS)

July 15 – 27, 2024

Organizing Committee:

Rolando de Santiago (California State University, Long Beach (CSU Long Beach))
Elizabeth Gillaspy (University of Montana)
Lara Ismert (Embry-Riddle Aeronautical University)
Brent Nelson (Michigan State University)

Using a combination of mini-courses, problem sessions, and expository talks, this program will provide graduate students with an accelerated introduction to the basics of operator algebras. GOALS aims to increase participation and retention in the field by persons from traditionally underrepresented groups by removing technical barriers to the field and building a strong community of support amongst the participants, contributors, and organizers. The program will conclude with a culminating workshop in which leading experts in operator algebras will provide accessible overviews of their research programs to participants.

Data on the number of women doctorates and underrepresented minority groups in mathematics and applied mathematics are well known. The steps after graduate course work can be even more difficult for students from these historically excluded groups, as few graduate programs have targeted mentoring support and guidance. Therefore, another important component of this program was networking, building a sense of community among peers, and professional development sessions.

Comments from our participant survey:

- At receptions/dinners where disposable utensils are provided, consider including (disposable) chopsticks, even if the food served isn't asian. Chopsticks can be easier to use than disposable forks :)
- I had a wonderful time at IPAM, thank you!

Long Program Opening Day

Mathematics of Intelligence

September 9, 2024

Long Program Tutorials Workshop

Mathematics of Intelligence

September 10 – 13, 2024

The workshop had the same organizing committee as the long program; the vast majority of participants were from the long program core. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds.

Long Program Workshop I

Analyzing High-dimensional Traces of Intelligent Behavior

September 23 – 27, 2024

Organizing Committee:
Vijay Balasubramanian (University of Pennsylvania)
Dora Biro (Rochester Institute of Technology)
Jacob Foster (Indiana University Bloomington)
Max Kleiman-Weiner (University of Washington)
Deanna Needell (University of California, Los Angeles (UCLA))

The study of biological intelligences has been transformed by breakthroughs in experimental and observational methods. New data have expanded our appreciation of the sophisticated behaviors exhibited by human and non-human animals across a range of taxa. Traces of intelligent behavior are typically high-dimensional, with complex structure in space and time. They often involve multiple data streams: for example, positional information from individual members of a bird flock, as well as "point-of-view" recordings showing what birds are looking at, moment by moment; or electrocorticographic recordings of human brain activity, as well as detailed traces of motor behavior. These traces are often buried beneath complex noise environments: individual animal movements must be pulled out of extensive visual clutter; whale song must be isolated from ocean noise.

This complex, high-dimensional data requires entirely new approaches to data representation, integration, and analysis. This workshop will focus on the challenges raised by high-throughput, high-dimensional studies of intelligent behavior. It will bring together experts in animal cognition, computational neuroscience, and cognitive science with mathematicians and computer scientists focused on relevant methods in machine learning, network science, high-dimensional statistics, and information theory.

Comments from our Participant Surveys:

- I went to the morning talks each day.
- One of the talks included math on chalk board and it was hard to follow for me, as a non mathematics major.
- Actually, most of the talks were not by mathematicians.
- These were extremely relevant talks and I learnt a lot about relevant methods.
- Simon Garnier's talk on swarms and slime molds inspired me to make a really cool model for collective motion that involves minimal spanning trees and the Vicsek bird update

rule. I'm really excited about the model and am talking to several folks in the program about it.
- I had trouble following some of the talks by non mathematicians, but I still enjoyed them a lot. The talks gave me a lot to think about, and that is more important than me having a line-by-line understanding.
- I had a great time - thank you for inviting me!
- It was a really cool workshop. As always, I am an advocate for fewer talks and more time to talk. I mostly went to the morning sessions because, if I am going to collaborate with IPAM folks in real time, I need some time for concentrated work on my own. For instance, during the five days of the workshop I used chat GPT to teach myself python. I went from "hello world" to a graphical user interface which implements a video game involving geometry and Galois theory in 5 days. This required some intense concentration outside the workshop. (I did this because I want to better talk with some IPAM folks who are using python to do deep learning.)
- Thank you to all organisers and the team for such an amazing conference!
- My only quibble, again, would be that there should be more time between talks.
- This was a great workshop.
- I think that you should have fewer talks and more time between them. Otherwise, the whole thing was great. As a totally random side comment, let me add that I really enjoyed having the bacon tray at breakfast each morning. That was awesome.

Long Program Workshop II

Theory and Practice of Deep Learning

October 14 – 18, 2024

Organizing Committee:
Misha Belkin (University of California, San Diego (UCSD))
Boris Hanin (Princeton University)
Julia Kempe (New York University)
Patrick Shafto (Rutgers University)

Modern neural networks operate at unprecedented scale. Their success in fields ranging from natural language processing (e.g., ChatGPT) to structural biology (e.g., AlphaFold) and computer vision (e.g., self-driving cars) is undeniable. Elucidating the nature of emergent properties of learning in these vast artificial intelligences — the central theme for this workshop — lies at the heart of both ML theory and practice.

Neural networks have confounded traditional ML beliefs about the dangers of overfitting and the nature of optimization in high dimensions. They have also given rise to many new empirical findings around feature/transfer learning, adversarial examples, compressibility, scaling laws (relating the size of datasets, models, and compute), the importance of adaptive optimization methods, and so on. What is needed to explain and predict all this is a rich new theory of learning capable of addressing the delicate interplay between model, data, and optimizers at large scale.

This workshop will bring together top researchers driving the frontiers of this work with experts in both theory and experiment for natural intelligence. The result will be a scholarly discussion on how to frame questions about learning and how to distill the similarities and differences between learning with biological and artificial systems.

Comments from our Participant Surveys:

- a very interesting and diverse set of talks
- It felt like the presentations of this workshop did not align well with the general theme of the program. It was way too targeted to a specific audience in a sub field of deep learning....
- I think it's difficult to put together a very diverse set of topics and make it relevant for everyone, so I think the organizers have done a great job already. It is just the fact that most topics are not directly relevant to my work.
- It would be even better if the program can support the transportation cost :)
- $350 limit for travel within California does not quite cover it. Air travel + Uber to/from airport is at least $400 and easily higher. It would make sense to increase the limit, especially given that
- it is a relatively minor expenditure.
- I really enjoy the workshop. I think it should be advertised to more students and postdocs.
- Wonderful workshop! Would be great if you could provide recommendations for restaurants nearby! It took some time to figure this out and prices have become very expensive these days.
- Really enjoyed the workshop!
- Food / snack options with less sugar would be ideal

Long Program Workshop III

Naturalistic Approaches to Artificial Intelligence

November 4 – 8, 2024

Organizing Committee:
Stephanie Forrest (Arizona State University)
Tom Griffiths (Princeton University)
Sumit Gulwani (Microsoft - Redmond, WA)
Martha Lewis (University of Bristol)
Josh Tenenbaum (Massachusetts Institute of Technology)

Many approaches to artificial intelligence are inspired by natural systems; for example, deep learning draws inspiration from biological neural networks. In recent years, researchers have looked to alternative biological inspiration. One paradigm develops distributed architectures for artificial intelligence, looking to biological evolution, insect swarms, and immune systems for models. Another paradigm argues that many forms of thinking are essentially equivalent to programming; this paradigm emphasizes the inference of (latent) programs from experience.

These paradigms have many appealing features. For example, evolutionary programming provides a powerful framework for search over machine learning architectures. Program

synthesis approaches (in the “thinking as programming” paradigm) can learn latent, interpretable programs for complex tasks beyond conventional deep learning approaches.

These naturalistic approaches lack a detailed theory that explains their power. Both cases involve optimization (sometimes, combinatorial optimization) over high dimensional, complex objective functions. Both also involve basic objects (like string-based representations or programs) with rich structure and few obvious symmetries, which have only recently been studied as mathematical objects in their own right.

This workshop will draw together researchers creating new algorithms and architectures (e.g., active symbol architectures, evolutionary programming approaches, neural program synthesis) with mathematicians and theoretical computer scientists who specialize in non-convex optimization, the theory of programming languages, type theory, proof theory, and category theory. It aims to promote cross-fertilization between these paradigms and more traditional approaches, while stimulating the development of rigorous foundations for evolutionary computing, program synthesis, and other naturalistic approaches to AI.

Comments from our Participant Surveys:

- The speakers delivered content at just the right level.
- Most of the talks were appropriate, though some were too detailed/required background knowledge which I did not have. I suppose this will be true for any conference with a wide range of talks/disciplines. Overall, I was satisfied with the content given the audience.
- seemed like experts only engaging with other experts. not willing to clarify or make talks accessible.
- It was a fairly closed group. The discussion period on Weds morning did not have an organized discussion. Some of the lectures were niche/non mainstream. A few of the lectures were very good.
- Fabulous workshop. I'm grateful to be invited. I learned new topics from multiple areas and advanced my knowledge from others. Well done!
- This was one of the best interdisciplinary workshops I have ever attended in my >20 years in academia! It is very difficult to make interdisciplinary workshops coherent. This was a rare instance where I paid full attention throughout the workshop despite the large variation in backgrounds and topics. The talks were excellent and at the right level. The opportunities for discussion allowed us to follow up. Well done to the organizers!
- This was possibly the most interesting and relevant academic event I attended in a few years. For context, I normally attend major AI and ML conferences every year. I would skip one of the big conferences to attend another workshop like this one. I love the format of the talks, where people have time to go deep into their research. I also like the friendly environment of people interrupting the talks to ask questions. I am going back home very satisfied with how much I learned in the workshop. Additionally, I connected with many relevant people I did not know before.
- this is not an inclusive space. its very elitist. people of interest and senior participants only speak to who they already know.
- IPAM is great.

- I was pleasantly surprised by the quality of the breakfast, specifically the breakfast burritos, breakfast bears (egg sandwiches) and fresh fruit. I liked that the lunch break was two hours -- shorter breaks make it difficult to walk to restaurants and order food in time. Minor point: at some sessions, people asked many questions (some of which seemed nit-picky) and this resulted in the session going over the allotted time. I would have preferred stronger moderation (i.e., moderators saying "Let's continue this discussion offline" when someone asks an extremely specific or tangentially related question).
- Ida, a core participant, is very aggressive and puts junior participants down. When trying to contribute to intellectual conversation, she has said very rude and offensive things to keep people out of the conversation or to question their knowledge of the field. I don't know why this is allowed by organizers or other people at IPAM.
- Overall, I thought that the workshop was excellent. I found the conversations outside of the workshop sessions to be just as valuable as the sessions themselves.

SPECIAL EVENTS AND CONFERENCES

PUNDiT: Practicum for Undergraduates in Inverse Problems and Data Assimilation

November 23 – 24, 2024

Organizing Committee:

Ricardo Baptista (California Institute of Technology)
Malena Espanol (Arizona State University)

"PUNDiT: (P)racticum for (Und)ergraduates (i)n Number (T)heory" is a 2-day intensive program which will showcase number theory broadly interpreted at the introductory level. A goal of this program is to expose Southern California students traditionally underrepresented in number theory (such as women and historically marginalized minorities) to the beauty of the subject.

The Practicum is introductory in nature and no prior number theory coursework will be assumed. Students should be familiar with Calculus and Linear Algebra, although this is not required. The Practicum is designed for students who have completed minimal coursework in upper-division mathematics courses.

PUNDiT will take place at IPAM in UCLA, and will feature:

- **Tutorials**: Two faculty members will rotate to give three lectures over two days to introduce topics in inverse problems and data assimilation.
- **Problem Sessions**: Two graduate students will coordinate a series of three hour-long group-work sessions where students will work on problems meant to supplement the tutorials.
- **Expository Talks**: Four experts will give one-hour introductory presentations on various combinatorial topics.
- **Professional Development:** The organizers will lead two workshops on REUs, CVs, asking for letters of recommendation, *etc.*

Long Program Workshop IV

Modeling Multi-Scale Collective Intelligences

November 18 – 22, 2024

Organizing Committee:

Iain Couzin (Max Planck Institute of Animal Behavior)
Pranab Das (Elon University)
Jessica Flack (Santa Fe Institute)
Govind Menon (Brown University)
Orit Peleg (University of Colorado Boulder)

All known intelligent systems are collectives. Individual organisms are collectives of cells, which develop, heal, sense, and act. Groups of human and non-human animals use a range of mechanisms to coordinate their behavior across space and time, from flocks and swarms to organizations, institutions, and cultural traditions. The brain is a collective of highly coupled and dynamic excitable cells. Deep learning—the dominant approach to artificial intelligence—gains its power from combining simple units into complex architectures; many contemporary architectures combine multiple learners, and multi-agent settings are a critical frontier for AI, especially settings that integrate human and artificial agents.

These examples imply that a scientific understanding of intelligence must grapple with collective intelligence—in a much broader sense than typical usage of the term would suggest. A variety of mathematical and computational models have been developed to explain and design intelligent behavior in particular collectives. Several mathematical fields provide the ideas behind these models, from dynamical systems, statistical mechanics, network science, and random matrix theory to information theory, optimization, Bayesian statistics, theories of self-assembly and self-organization, game theory, and category theory.

This workshop will bring together leading experts in the mathematical modeling of collective intelligence. While the workshop will explore collective intelligence in many different systems, substrates (both natural and artificial), and scales, it will focus on three broadly applicable modeling frameworks: dynamical systems, which have been applied to systems as various as brains and insect swarms; statistical physics, which has illuminated the behavior of flocking birds and deep learning architectures; and game theory, which has been applied to animal, human, and AI collectives. The collective intelligence domain cultivates the further development of formal tools for treating compositionality; the emergence of new capacities and collective degrees of freedom at multiple scales; and the higher-level institutions that coordinate the intelligent behavior of lower-level parts.

Comments from our Participant Surveys:

- Talks were difficult to understand.
- Fantastic workshop and extremely stimulating lectures
- This was truly an amazing conference with some of the best presentations/papers I've ever seen.
- all talks were amazing.
- The diversity of backgrounds/expertise was a highlight of the workshop.

- yes, the complementary non-mathematical talks were really well chosen by the organisers, relevant and well delivered.
- All speakers made efforts to make talks accessible and engaging.
- Seems to be negative relationships among core participants.
- My only suggestion is that having a second reception later in the week would have been a helpful opportunity to encourage discussion after we had become acquainted with each other's work.
- More vegan options (always labelled) and no meat, given how much it contributes to CO2 emissions. Many conferences go vegetarian with lots of vegan options, as it's cheaper and more sustainable.
- The cap of $1200 for travel is too less for those coming from India and other parts of Asia. Please revise it to $1800.
- This was a fantastically organized workshop. The set of speakers was terrific, which led to a lot of engaging discussions during the breaks and outside of the workshop. I think that some of these discussions will lead to collaborations! Thank you for inviting me to this.
- White people only talk with white people. Seniors only talk with seniors. I wish there had been more engagement from the junior participants but perhaps that's due to the culture seniors create. It does not seem inclusive or supportive. When junior participants try to speak up about issues, their complaints seem to be brushed under the rug or ignored.
- More female speakers!
- One of the best academic environments I have been in - I hope to be able to return some day!
- No recommendations. It was exceptionally well run.
- It will be helpful if IPAM books the air tickets for the speakers.

LONG PROGRAM CULMINATING WORKSHOP AND REUNION CONFERNCES

UCLA Lake Arrowhead Conference Center
December 9 - 13, 2024

IPAM long programs end with a culminating workshop for long-term ("core") participants. Additionally, participants from past IPAM long programs are usually invited to two reunion conferences, which take place 1.5 and 2.5 years following the completion of their long programs. Thus, normally, there are three groups at the IPAM Lake Arrowhead event: the core participants from the recently completed program (attending the culminating workshop), and the first and second reunions of two past long programs.

These co-located culminating and reunion conferences allow IPAM to track evolution of ideas we helped incubate, and plant seeds for future scientific directions. The 5-day conferences allow participants to present the research results and publications initiated by the long program but take a year or two to mature, and to further develop collaborations. The reunion conferences also help IPAM assess its success at building a successful and vital research community.

Culminating Workshop

Mathematics of Intelligence

December 9 - 13, 2024

IPAM long programs end with a culminating workshop for long-term ("core") participants. The workshop is held at the UCLA Lake Arrowhead Conference Center. The organizing committee is the same as for the long program itself. The purpose of the workshop is to summarize what is learned during the program. Working groups that formed during the long program give reports about their progress. Additionally, all participants collaborate to produce a White Paper, which serves to both capture developments discussed during the program itself and to map out potential future developments. The white paper is available at the IPAM web site, https://www.ipam.ucla.edu/reports/white-paper-mathematical-and-computational-challenges-in-quantum-computing/

Comments from our Participant Surveys:

- We needed more electrical plugs and extension cords in the meeting room. The WiFi was pretty poor everyone on site.
- Scheduling the joint sessions so late in the evening made it difficult for participants to fully engage and contribute. In the future, it would be much more effective to hold these sessions earlier in the day when everyone has more energy and focus.
- I was so glad that we had some outgoing participants that made the social hours so active and hands on. Really pleased. The facilities were conducive to networking and intellectual discussion.
- Thank you IPAM! And thank you organizers, especially Jacob!!! Transformative experience.
- This was so fun, and an excellent way to wrap up the program. I found the program activities specific to MOI extremely productive and beneficial, but I did not find as much value in the joint sessions with the other programs. This may be because the topics/disciplines were too different, or because I struggled to find opportunities to connect with the other program members.

Reunion Conference

Advancing Quantum Mechanics with Mathematics and Statistics

Reunion Conference II

December 9 - 13, 2024

This reunion occurred on-time, 2.5 years after the completion of the program. An alumni survey of the program was performed after this reunion, since this was the last activity associated with the long program. Our exit survey gathered 7 responses. A majority of the participants indicated that their involvement in the long program at IPAM had a positive impact on their research, collaborations, and career. Participants were asked to indicate their agreement by checking the corresponding boxes for the statements that applied to them.

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our Participant Surveys: None

Reunion Conference

New Mathematics for the Exascale: Applications to Materials Science

Reunion Conference I
December 9 - 13, 2024

This reunion occurred 1.5 years the completion of the program and an alumni survey of the program was performed after this reunion. At the end of the 3-month long program, our exit survey gathered 16 responses. About 50% of those who responded self-identified as recent PhDs (5 years or less from PhD), and 43.75 % identified as having received a PhD more than 5 years before the program. About one third of those responding identified as a mathematician or a statistician (18.75%), followed by Physical Sciences (62.5%) and Engineering (18.75%).

The table below summarizes responses to the question on the value of program activities. Generally, participants rated all program components highly.

	1-POOR	2	3	4-EXCELLENT	N/A	TOTAL
Value of Opening Day activities.	0.00% 0	0.00% 0	12.50% 2	75.00% 12	12.50% 2	16
Quality or usefulness of the series of workshops.	0.00% 0	6.25% 1	18.75% 3	75.00% 12	0.00% 0	16
Quality or usefulness of the activities between workshops.	0.00% 0	6.25% 1	12.50% 2	81.25% 13	0.00% 0	16
Value of the Culminating Workshop.	0.00% 0	0.00% 0	12.50% 2	81.25% 13	6.25% 1	16
Overall merit or quality of the long program.	0.00% 0	0.00% 0	6.25% 1	93.75% 15	0.00% 0	16

Comments include: "*This long-term program was truly great! I learned lots of new stuffs from this program*" and "*Very much enjoyed the program and found it very useful*".

Overall, most participants were very satisfied with IPAM resources. The table below summarizes responses:

	1 - VERY DISSATISFIED	2	3	4 - VERY SATISFIED	N/A	TOTAL
Facilities (your office, the lecture hall, etc.)	0.00% 0	0.00% 0	6.25% 1	93.75% 15	0.00% 0	16
Program staff support	0.00% 0	0.00% 0	6.25% 1	93.75% 15	0.00% 0	16
Computing resources and support	0.00% 0	0.00% 0	25.00% 4	68.75% 11	6.25% 1	16
Housing resources and support	0.00% 0	0.00% 0	31.25% 5	62.50% 10	6.25% 1	16
A supportive and inclusive environment for all program participants	0.00% 0	0.00% 0	0.00% 0	100.00% 16	0.00% 0	16
Financial support and reimbursement process	0.00% 0	12.50% 2	6.25% 1	75.00% 12	6.25% 1	16
Online resources	0.00% 0	0.00% 0	25.00% 4	68.75% 11	6.25% 1	16

Comments included positive comments such as "*thank you so much to all the IPAM staff for the support they provided us during the long program*", "*the IPAM staff is excellent. They were always extremely helpful and contributed to the overall great experience I had during my participation in the NME2023 program"*, and "*the support staff were absolutely excellent. Couldn't have asked for any more support from each of them"*, as well as some critical comments, such as "*The reimbursement process is very slow: I still have not received funds to cover my second month (and we are now at the end of the programme). I know this is not IPAM's fault, but please apply pressure to the UCLA finance department to try to improve things! The slowness of reimbursement is particularly challenging for junior participants, and can have a serious impact on creditworthiness of your participants*."

The majority of participants liked collaborative opportunities they had at IPAM. The table below summarizes their responses:

	NONE	LOW	MEDIUM	HIGH	TOTAL
Collaboration within your discipline or sub-discipline.	0.00% 0	0.00% 0	25.00% 4	75.00% 12	16
Collaboration outside your discipline or sub-discipline.	0.00% 0	6.25% 1	18.75% 3	75.00% 12	16
Collaboration between junior and senior participants.	6.67% 1	6.67% 1	13.33% 2	73.33% 11	15

More than 75% rated the possibility to collaborate outside one's discipline or sub-discipline as "high", which illustrates the highly interdisciplinary nature of this program. Almost 75% of participants responded that the possibility of collaboration between a junior and senior participant was "high".

Most participants agreed when presented with statements about the program meeting their expectations and being of help with furthering their career and research goals. The table below summarizes these responses:

	1 - STRONGLY DISAGREE	2	3	4 - STRONGLY AGREE	TOTAL
The IPAM long program met my expectations.	0.00% 0	0.00% 0	6.25% 1	93.75% 15	16
The long program will have a positive impact on my research and career.	0.00% 0	0.00% 0	12.50% 2	87.50% 14	16
The long program was a valuable mentoring opportunity for the "junior" participants.	0.00% 0	6.25% 1	6.25% 1	87.50% 14	16
I formed new collaborations that will lead to publications or other outcomes.	0.00% 0	6.25% 1	18.75% 3	75.00% 12	16
I would participate in another IPAM long program.	0.00% 0	0.00% 0	0.00% 0	100.00% 16	16

Comments included: "*I think the culminating retreat played an important role in consolidating the results of the long program. Without that final focus, things might have fizzled out", "The program was truly a life-changing experience both from a career point of view and from a personal point of view. I am very grateful that I was able to attend"*, and "*thank you again for organising a wonderful programme"*! As well as more critical comments: *"My only criticism is small but I would say that the reimbursement of funds was relatively slow and left some people (mostly the junior attendees) struggling to get by with rent payment back at their home location alongside their air-bnb payments"* and *"any improvement to the speed at which reimbursements are processed would make IPAM a more accessible place for all researchers"*.

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our Participant Survey after the reunion conference:

- Great discussions between all three programs that met concurrently.
- The facilities at lake arrowhead, including inside the lodge and the balls at the basketball court, are very outdated.
- Great workshop!
- I had an amazing time as usual. Thank you to the whole IPAM team!
- The reunion workshop was very interesting - great progress, many interesting discussion, very lively. I enjoyed the interaction with the colleagues tremendously and am looking forward to the next reunion.
- This was a terrific reunion workshop!!!

WINTER WORKSHOP

Rotating Turbulence: Interplay and Separability of Bulk and Boundary Dynamics

January 27 – 31, 2025

Organizing Committee:

Jonathan Aurnou (University of California, Los Angeles (UCLA))
Susanne Horn (Coventry University)
(Keith Julien) (University of Colorado Boulder)
Rudie Kunnen (Technische Universiteit Eindhoven)

This IPAM workshop will bring together the rotating turbulence community to address the complex interplay between boundary and bulk dynamics in rotating convection systems. A successful meeting will yield new theoretical, numerical and laboratory approaches for both deconvolving boundary from bulk processes and for better modeling how the boundary and bulk flows interact and alter each other. Such knowledge is necessary for building the next generation of geophysical and astrophysical fluid dynamical turbulent transport schemes and for elucidating when boundary phenomena will dominate over bulk processes in natural systems. This workshop also honored the work and contributions to the field by the late Keith Julien.

Comments from our Participant Surveys:

- I wouldn't say there were lectures by any pure mathematicians, but the overall quality of the lectures (some by applied mathematicians) was high.

- The scope and quality of the lectures was extremely high. This workshop was very beneficial and enjoyable.
- Although the title of the workshop was "bulk and boundary dynamics", the talks had a clear bias toward wall modes (boundary dynamics only).
- Numerical mathematics is very much a key approach to study turbulent flows.
- This is an amazing workshop. It matches my interest perfectly, and I've been meeting amazing people here.
- There was one mathematician's lecture that could have been better. But they have always been a bit off.
- The lectures were at a higher level than those at many conferences -- and that's what I came for!
- I think the workshop would have benefitted from more time for interactions and fewer/shorter talks. However, I was pleasantly surprised by the higher-than-usual quality of talks.
- The spirit was excellent with plenty of discussions during the talk.
- The 50+10 minute talks every day were a bit long or too many. It would have been nice to have some extra time just set aside for discussion in one or two afternoons instead.
- I think more time could be given to discussion, as the 15 minute breaks after each talk were a little short.
- The schedule could have some more room for informal discussions, perhaps by leaving out a speaker slot here or there.
- I wish there was one less 50 minute lecture a day. OR 35 - 40 minute lectures, with more time in the day to chat and discuss the posters. Five 50-minute lectures per day left too little time for lengthy discussion.
- It would have been nice to have longer breaks in the morning (30 minutes), by reducing a bit the length of the talks (40 minutes would be enough). I would have liked to have one free afternoon in the week, to have the opportunity to meet and discuss in depth with other participants.
- More informal discussion time would have been nice.
- The talks were too long and breaks between / other activities too short. We had 1 hour talks
- (50min+10min questions) and 15min breaks. It would have been **much** better to have 45min talks (30min+15min discussion) and 30min breaks, at least. That would allow actually utilizing the available IPAM spaces for discussions. Instead the breaks were just enough for people to get coffee, use the restroom, say hi a bit, etc., but not long enough to really engage in a scientific discussion. In fact, several people were planning to skip talks in order to have extended time to talk with each other.
- Lots of interaction, lots of questions during talks, excellent discussion.
- The talks were too long and too dedicated to a lecture rather than discussion format. The long lunches prompted some collaborative discussions, and ability to educate students, but many of the talks were little different from a workshop at a major conference. This, in my mind, is not an appropriate setting for people to be presenting their own personal work for an hour at a time, especially when that work is (several) decades old. I'd suggest shorter talks, if any, and maybe half-days dedicated to hands-on tutorials. One could focus on using open-source tools for simulating geophysical flows (e.g., Rayleigh, Dedalus, etc.). One could be dedicated to building small, simple lab or public

demonstrations. The later occurred in the margins, hosted by the DIYnamics team with legos to assemble rotating turntables and similar, but I only became aware of it after the fact and the only ability to engage with the demo/tutorial was to skip afternoon talks. Cancel the talks and get everyone engaged. We'll all learn something working together.

- Perhaps one thing to consider: the long lectures were great to go into the detail and allow for on-the-fly discussions but the breaks were a little too short to allow for impromptu discussions between participants. A few longer breaks would probably help maximise the benefit of the workshop. Otherwise, outstanding workshop both in scope, quality of presentation, spirit of the participants and choice of lecturers.
- I thought this was a great workshop. The selection of speakers was very good, and I came away learning something from most of the talks. My only suggestion for future workshops would be to allocate more time for discussion into the schedule. The coffee breaks were only just long enough for discussions to get started. Reducing the total time per presentation from 1 hour to 50 or 45 minutes could probably help with this. Otherwise, this was an absolutely fantastic workshop – far more useful than other meetings that I've attended in the past few years.
- I thank IPAM for a great week! My main recommendation is to leave a bit more time in the schedule for informal discussion, or perhaps even planned, moderated discussions on predetermined topics.
- Great workshop. Appreciated by everyone I talked to at the workshop, grad students to emeritus. Breakfast worked flawlessly. My one change would be to have a daily coffee hour after lunch in the poster area to facilitate discussions. Lack of time for lengthy discussions was the one (easily addressable) weakness of this event.
- Thank you for a great workshop! :) 7 Perhaps reduce the talk time to 40 minutes and this would allow for slightly longer breaks and discussions. Other than that the conference was great!
- The workshop was excellent in all ways, thank you! My only suggestion would be to have more unscheduled time to allow informal discussions. Perhaps one less talk per day, noting that I liked the 50 minute talk plus 10 minutes of Q&A format.
- This is an awesome workshop.

SPECIAL EVENTS AND CONFERENCES

Quantum Winter School: Quantum Error Suppression, Mitigation, and Correction

February 3 – 5, 2025

Organizing Committee:

Richard Ross (University of California, Los Angeles (UCLA))
Birgitta Whaley (University of California, Berkeley (UC Berkeley))
Eric Hudson (University of California, Los Angeles (UCLA))
Jason Cong (University of California, Los Angeles (UCLA))

The Challenge Institute for Quantum Computation (CIQC) together with the Institute for Pure and Applied Mathematics (IPAM) are pleased to present the Fifth annual Winter School in Quantum Information Science. This year's school will return its focus to the topic of our first school, Quantum Error Correction, held in early 2021. Enormous progress has been made in the

field, in particular experimental demonstrations of error suppression and mitigation schemes and demonstrations of a number of quantum error correcting codes.

The school will provide an in-depth primer of classical and quantum error correction, a survey of recent experimental advances, and a tutorial on current research in advanced error correction approaches. The school is aimed at experimentalists and new theory students working in quantum information science and related fields. We aim to convene a multidisciplinary group of students and researchers who will disseminate and accelerate developments in the field, and to draw on their own research to help inspire new approaches and application domains. Applications are now being accepted. Financial support will be offered to young researchers subject to demonstrated need and availability.

Comments from our Participant Surveys: None

WINTER WORKSHOP

Computational Interactions between Algebra, Combinatorics, and Discrete Geometry

February 10 - 14, 2025

Organizing Committee:

Matthias Beck (San Francisco State University)
Daniel Erman (University of Hawaii at Manoa)
Selvi Kara (Bryn Mawr College)
Andrés Vindas Meléndez (Harvey Mudd College)

Over the last half a century, Algebra, Combinatorics, and Discrete Geometry have undergone transformations due, in part, to the connections each of these areas have to other fields and the growth of computational approaches used in the study of theoretical mathematics. These areas are closely intertwined, with various algebraic, combinatorial, and geometric objects playing pivotal roles. These objects include monomial ideals, affine semigroup rings, Stanley-Reisner rings, Ehrhart rings, toric rings, Cox Rings, Chow Rings, Gröbner bases on the algebraic side; graphs, matroids, simplicial complexes, polytopes and polyhedral complexes, convex bodies, posets, lattices, arrangements of hyperplanes on the combinatorial and discrete geometry side.

As researchers continue to create new connections and build bridges between these areas, computational tools in the field have significantly evolved. The workshop's primary goal is to deepen the understanding of the interconnectedness between algebra, combinatorics, and discrete geometry, with a strong emphasis on the importance of computational tools. Furthermore, this workshop will serve as a systematic attempt to facilitate the collaboration between mathematicians in each of these areas who might not have the opportunity to regularly collaborate or who are interested in expanding their mathematical toolbox to include tools from each of the three main areas to their current work. It is our hope that by bringing together mathematicians with different approaches to their mathematics, there will be unexpected connections made.

Comments from our Participant Surveys:

- Great workshop!
- These talks were well-curated! 3 What a great combination of speakers in algebra and combinatorics!! It was a pleasure to learn from so many different kinds of people!!
- The lectures were excellent in both content and presentation. It's clear that the speakers weren't just chosen because their research is excellent, but also because they can effectively communicate complex ideas.
- The talks were excellent.
- The lectures were great.
- Some talks were too difficult to comprehend, but overall a good selection of different topics in the field and I would not change them. It was nice to have the space to interact with both collaborators and unfamiliar faces from different fields.
- Workshop was excellent and was beneficial to my mathematical career! Breaks were good – I did have a hard time breaking the ice at times.
- This is more like a conference than a workshop. Being called a workshop, I would expect more time to learn concepts through collaboration. However, there was only one hour dedicated to collaboration.
- The talks were well-tailored to the audience. Additionally, the atmosphere at the workshop was so positive and encouraged free discussion of questions and ideas.
- I wish there had been more time for informal mathematical conversations. I felt like there were too many talks.
- This conference was very thoughtfully-organized.
- It was good to have the problem session and the collaboration session. It would have been nice to have another collaboration session on Wed and Thurs.
- Wish there were was more workshop time
- One participant asked an outsized number of questions, and the organizers didn't set norms ahead of time that enabled them to interrupt this behavior.
- I registered late December and I wish I had received more information about the workshop beforehand (I only received two emails, one about the poster and one with information).
- I wish the workshop also covers travel expenses.
- The IPAM resources were great! The staff clearly knew how to support a conference and did a great job facilitating.
- Great workshop, thanks for organizing!
- The talks were very interesting and extremely well presented, I appreciate the work that went into preparing this experience. I was a little confused that this conference was called a "workshop". All the other conferences I have attended that have been called workshops were more coordinated sequences of lectures that built on each other such that I learned something specific over a series of days. While this conference was very lovely, all of the talks were by different individuals, and did not a priori build on each other in this way. The advertisement felt a little misleading honestly. I may not have attended had I known that it was individual talks a week long. I'm glad I went, perhaps alter the message in the future or give organizers more flexibility in planning.
- Thank you IPAM! Only possible comment would be to give restaurant recommendations.
- Everything was amazing! My only suggestion is to build in a half day off in the schedule for a conference excursion.

- Thank you!
- This was the best math experience and community that I've participated in for quite a while. I learned a lot and met some very exceptional folks. My only comment is that there needed to be more collaboration time. I understand that that was a restriction from IPAM I encourage IPAM to give organizers more flexibility. I thinks folks here were very excited and eager to work with each other and would have made good use of more of an opportunity to do so.
- Thank you so much! IPAM is a wonderful place to do mathematics.
- I enjoyed my first workshop at IPAM, thank you all!
- This was a fantastic workshop. Thanks to IPAM for wonderful facilities and staff, and thanks to the organizers for putting together such an amazing group of people!
- This workshop was fantastic. I had a great time. The talks were interesting, and the participants were very friendly and accommodating.

WINTER WORKSHOP

Free Entropy Theory and Random Matrices

February 24 – 28, 2025

Organizing Committee:

Rolando de Santiago (California State University, Long Beach (CSU Long Beach))
Ben Hayes (University of Virginia)
Srivatsav Kunnawalkam Elayavalli (University of California, San Diego (UCSD))
Brent Nelson (Michigan State University)
Nikhil Srivastava (University of California, Berkeley (UC Berkeley))

Free probability was introduced by Voiculescu in the 80's in an attempt to study the notorious free group factors, which are certain fundamental—and in many ways prototypical—examples of von Neumann algebras. The subject has been intimately connected with random matrix theory ever since Voiculescu's breakthrough result that the large N-limits of independent random matrices are freely independent. The notion of free entropy, which quantifies this connection, has recently seen spectacular success in applications to von Neumann algebras, including the resolution of the long-standing Peterson–Thom conjecture through the use of Hayes's 1-bounded entropy.

Free probability has transformed into an interdisciplinary field connecting operator algebras, harmonic analysis, probability, and combinatorics. This workshop will bring together experts and early career researchers from operator algebras and random matrix theory to better understand this intersection and expand the reach of free entropy methods. Topics will include:

- Free entropy dimension and 1-bounded entropy
- Strong and weak convergence of laws in random matrix theory
- Applications to von Neumann algebras, random graphs, and other topics
- Consequences of the resolution of the Peterson–Thom Conjecture

Comments from our Participant Surveys:

- A few talks were out of scope

- There was only 1 talk of this type by a physicist. Great talk!
- Having an all-gender bathroom would be appreciated
- It would have been nice is a list of participants (not just speakers) were available on the website, even if only to participants.
- It was a great workshop and very well run.

SPECIAL EVENTS AND CONFERENCES

Latinx in the Mathematical Sciences Conference 2025

March 6 – 8, 2025

Organizing Committee:

Selenne Bañuelos (Institute for Pure and Applied Mathematics)
Mario Bañuelos (University of California, Merced (UC Merced))
Cynthia Flores (California State University, Channel Islands (CSU Channel Islands))
Juan Meza (University of California, Merced (UC Merced))
Anthony Várilly-Alvarado (Rice University)

IPAM hosted this conference showcasing the achievements of Latinx in the mathematical sciences. The goal of the conference is to encourage Latinx to pursue careers in the mathematical sciences, to promote the advancement of Latinx currently in the discipline, to showcase research being conducted by Latinx at the forefront of their fields, and, finally, to build a community around shared academic interests. The conference will be held on the UCLA campus in Los Angeles, CA.

This conference was also sponsored by the **Mathematical Sciences Institutes Diversity Initiative**, with funding from the National Science Foundation Division of Mathematical Sciences.

Pre-Conference Activity for Students: Several math professors led a session for undergraduates and graduate students only. The students will learn how to communicate their research effectively, including both posters and oral presentations. Students selected to present a poster at the Latinx in Mathematics Conference were required to attend this activity.

Comments from our Participant Surveys: None

LONG PROGRAM

Non-commutative Optimal Transport

March 10-June 13, 2025

Organizing Committee:

Tryphon Georgiou (University of California, Irvine (UCI))
Augusto Gerolin (University of Ottawa)
Farnaz Heidar-Zadeh (Queen's University)
Katarzyna Pernal (Politechnika Lodzka)
Alessandro Rudi (Ecole Normale Supérieure)
Dario Trevisan (Università di Pisa)
Oliver Tse (Eindhoven University of Technology)

In the last decades, optimal transportation (OT) has emerged as a fertile field of inquiry, and an effective tool for the diverse exploration of applications within and beyond mathematics, including economics, meteorology, geometry, statistics, fluid mechanics, engineering, and design problems.

More recently, motivated by fundamental problems in Artificial Intelligence, Quantum Physics, and Electronic Structure Theory, the theory of OT has been broadening to a different class of state spaces such as the spaces of density matrices, operators, or more generally C* and von Neumann algebras, all of which are non-commutative. Although these non-commutative OT variants share a common mathematical feature, a unified geometrical perspective for them is still lacking. Additionally, many crucial analytical, computational, and statistical challenges remain unsolved, impeding the development of practical applications.

The program brings together and fosters collaborations among researchers from complementing mathematical communities that have been or are keen on working on the topic. More specifically, the program will focus on:

- Evolution equations for density operators
- Quantum optimal transport
- Wasserstein distances for density operators
- Semidefinite relaxation of non-commutative transport
- Statistical and probabilistic aspects of non-commutative transport
- Matrix and Operator Functional inequalities
- Computational algorithms solving non-commutative optimal transport

Long Program Tutorials Workshop

Non-commutative Optimal Transport
March 11-14, 2025

The workshop had the same organizing committee as the long program; the vast majority of participants were from the long program core. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds.

Long Program Workshop I

Optimal Transport for Density Operators: Theory and Numerics

March 31 – April 4, 2025

Organizing Committee:
Eugene De Prince (Florida State University)
Augusto Gerolin (University of Ottawa)
Katarzyna Pernal (Politechnika Lodzka)
Dario Trevisan (Università di Pisa)

The quest to devise a non-commutative counterpart of the Monge-Kantorovich optimal transport theory began about thirty years ago with early proposals by A. Connes and D. Voiculescu. These early attempts focused mostly on the static Monge and Kantorovich formulations using duality

theory. More recently, several formulations for the non-commutative counterpart of the Optimal Transport problem and Wasserstein distances have been proposed motivated by computational challenges and applications in Theoretical Chemistry and Quantum Physics.

The primary goal of this workshop is to foster collaborations and build bridges between three disjoint worlds of non-commutative (static) optimal transport, on both theoretical and computational aspects as well as potential developments in Quantum Physics and Electronic Structure Theory. This includes

- Monge-Kantorovich formulation of Non-commutative Optimal Transport
- Operator and Tensor Scaling
- Quantum Optimal Transport between quantum channels and qubits
- Optimal Transport Methods in Density Functional Theory
- Developments in Reduced Density Matrix Functional Theory
- (Static) Optimal Transport Theory for von-Neumann algebras

Comments from our Participant Surveys:

- Excellent lectures
- Electronic structure is uninteresting to me, and the first and second days were mostly electronic structure talks.
- Some of the lectures was too technical for non mathematicians
- The staff are the nucleus of IPAM and they have done, and continue to do, an amazing job.
- This was a wonderful and stimulating workshop, supported by an environment that encouraged discussion.

Long Program Workshop II

Dynamics of Density Operators

April 28 – May 2, 2025

Organizing Committee:

Tryphon Georgiou (University of California, Irvine (UCI))
Leonard Monsaingeon (Group of Mathematical Physics of the University of Lisbon (GFMUL))
Oliver Tse (Eindhoven University of Technology)

The quest to devise a non-commutative counterpart of the Monge-Kantorovich optimal transport theory began about thirty years ago with early proposals by Connes and Voiculescu. These early attempts focused mostly on the static Monge and Kantorovich formulations using duality theory. At about the same time, a dynamical reformulation of optimal transport was taking place in the works of Benamou and Brenier, McCann, and Otto. The ensued recasting of the Fokker-Planck equation as the gradient flow of the free energy in the Wasserstein metric by Jordan, Kinderlehrer and Otto proved pivotal, with applications from geometry to fluid mechanics and thermodynamics.

As a result of these developments, a new angle for casting dynamics in a non-commutative environment emerged. The first proposal was put forth by Carlen and Maas to devise a gradient

flow theory in the quantum setting. In parallel to this entropy-centric dynamical template, a rich mosaic of alternatives drew upon the early Connes' proposal and on the Riemannian structure of statistical manifolds, to devise natural metrics and geodesic flows in the space of positive Hermitian and density operators.

This developing landscape has left us with several natural questions. What are underlying unifying principles? Which of these structures provide implications in quantum physics? Can these structures predict new physical properties, such as natural time constants of quantum processes? Can functional inequalities and rates provide answers to these questions? Is there a natural notion of curvature that dictates non-commutative flows and brings further insights into quantum evolutions? Is there a stochastic model for non-commutative transport?

With many questions and few answers, it is our hope and expectation that the workshop will provide creative feedback and help spur further progress on this fast-developing subject. Complementing views will help focus, specifically, on problems of potentially great physical significance.

Comments from our Participant Surveys:

- Everything was excellent! 2 thank you very much!
- it was a great experience for me to attend the event!
- It would be great if there were certain changes for the breakfast menu, maybe more variety sandwiches, and not just egg +cheese (+bacon), an option without an egg would be great. The fruit selection is amazing by the way.

Long Program Workshop III

Statistical and Numerical Methods for Non-commutative Optimal Transport

May 19 – 23, 2025

Organizing Committee:
Tom Hutchcroft (California Institute of Technology)
Richard Kenyon (Yale University)
Gady Kozma (Weizmann Institute of Science)
Asaf Nachmias (Tel Aviv University)
Perla Sousi (University of Cambridge)

While classical "integrable" statistical mechanics has been restricted to one and two dimensions, recent ideas have extended our understanding to (some) higher dimensional situations, or to models on non-planar graphs. These include graph limits, posets, multinomial models, random complexes and random groups, and more. While these topics are quite diverse, they nonetheless have common tools, notably the use of random walks, the graph laplacian, homology theory, and determinants. Topics will include: Benjamini-Schramm limits of graphs, unimodular measures, spanning trees and spanning complexes, chip firing/sandpile models, matroids, higher determinantal processes, random complexes, multinomial models, random groups, rigidity, and statistical physics in more than two dimensions.

Comments from our Participant Surveys:

- Excellent presentations. I was able to learn a lot about the ongoing research on this topic
- Overall great experience
- I generally thought the workshop was of very high quality --- the IPAM organization is excellent, the quality of talks was extremely high, and I had the chance to have many meaningful conversations throughout. My only constructive criticism is that the set of topics was perhaps too broad given the small number of participants. I feel that a small meeting of this size presents an opportunity to bring researchers from different backgrounds to have focused talks/discussions on 1-2 themes. In this case, there were certainly many backgrounds represented, but the set of themes across talks was equally far-reaching. I feel that this makes it more difficult to make substantive conceptual progress as compared to other workshops of this size that I have attended.
- Superb topics, environment, organization, and Staff.

GREEN FAMILY LECTURE SERIES

Lectures by Alessio Figalli: Optimal Transport: From A to B… and Beyond" and "Exploring Stability in Geometric and Functional Inequalities: OT and Beyond" delivered on May 19, 2025 and May 20, 2025, respectively.

Long Program Culminating Workshop and Reunion Conferences

UCLA Lake Arrowhead Conference Center
June 8 – 13, 2025

IPAM long programs end with a culminating workshop for long-term ("core") participants. Additionally, participants from past IPAM long programs are usually invited to two reunion conferences, which take place 1.5 and 2.5 years following the completion of their long programs. Thus, normally, there are three groups at the IPAM Lake Arrowhead event: the core participants from the recently completed program (attending the culminating workshop), and the first and second reunions of two past long programs.

These co-located culminating and reunion conferences allow IPAM to track evolution of ideas we helped incubate, and plant seeds for future scientific directions. The 5-day conferences allow participants to present the research results and publications initiated by the long program but take a year or two to mature, and to further develop collaborations. The reunion conferences also help IPAM assess its success at building a successful and vital research community.

Culminating Workshop

The Non-commutative Optimal Transport long program ended with a culminating workshop at the UCLA Lake Arrowhead Conference Center. The organizing committee is the same as for the long program itself. The purpose of the workshop is to summarize what is learned during the program. Working groups that formed during the long program give reports about their progress. Additionally, all participants collaborate to produce a White Paper, which serves to both capture developments discussed during the program itself and to map out potential future developments. The white paper is available at the IPAM web site, https://www.ipam.ucla.edu/reports/white-paper-geometry-statistical-mechanics-and-integrability/

Comments from our Participant Surveys:

- I had many opportunities to talk to NOT2025 and CQC2023 participants about my career plans.
- For the sake of last-minute work on presentations, it would be nice if the wifi was better in the cabins. But I think that is outside the control of IPAM.

Reunion Conference

Computational Microscopy
Reunion Conference II
June 9 – 13, 2025

This reunion occurred 2.5 years after the completion of the long program. An alumni survey of the program was performed, since this was the last activity associated with the long program. The survey gathered 9 responses. A majority of the participants indicated that their involvement in the long program at IPAM had a positive impact on their research, collaborations, and career. Participants were asked to indicate their agreement by checking the corresponding boxes for the statements that applied to them.

At the completion of the program, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our Participant Surveys:

- Superb group and organization, thank you!
- The idea of the Joint Session Symposiums is great, but sometimes it is hard to follow the talks, especially after a long day of other talks and discussions. Following the talk from the speaker of my own long program was fairly easy, but it was a lot more difficult for me to follow the other two talks. I would suggest to communicate to the speakers to make their talk easier to understand by a broader audience or, perhaps, reserve the first 15-20 minutes for an introduction to the topic explaining all of the relevant basics.
- Everything was wonderful as always. IPAM is a treasure and I wish it continued success in the future. Math changes everything!
- Thank you so much for all! What a great experience and wonderful connections in and out of our fields.

Reunion Conference

Mathematical and Computational Challenges in Quantum Computing
Reunion Conference 1

This reunion occurred 1.5 years the completion of the program. An alumni survey of the program was performed, since this was the last activity associated with the long program. The long program exit survey gathered 13 responses. About 77% of those who responded self-identified as recent PhDs (5 years or less from PhD). More than one third of those responding identified as a mathematician or a statistician (53%) followed by Physical Science (31%), computer scientists (8%) and Chemistry (8%).

The table below summarizes responses to the question on the value of program activities. Generally, participants rated all program components highly.

	1-POOR	2	3	4-EXCELLENT	N/A	TOTAL
Value of Opening Day activities.	0.00% 0	7.69% 1	15.38% 2	61.54% 8	15.38% 2	13
Quality or usefulness of the series of workshops.	0.00% 0	7.69% 1	7.69% 1	84.62% 11	0.00% 0	13
Quality or usefulness of the activities between workshops.	0.00% 0	0.00% 0	38.46% 5	61.54% 8	0.00% 0	13
Value of the Culminating Workshop.	0.00% 0	7.69% 1	15.38% 2	53.85% 7	23.08% 3	13
Overall merit or quality of the long program.	0.00% 0	0.00% 0	7.69% 1	92.31% 12	0.00% 0	13

Comments included positive comments such as "*This was a truly great program and I have had much benefit for my research" and "Loved it!"*, as well as some critical comments, such as "*I think in the future organizers should commit to some time, not on workshop weeks, to spend some time with the long participants and working groups.*"

Overall, most participants were very satisfied with IPAM resources. The table below summarizes responses:

	1 - VERY DISSATISFIED	2	3	4 - VERY SATISFIED	N/A	TOTAL
Facilities (your office, the lecture hall, etc.)	0.00% 0	0.00% 0	15.38% 2	84.62% 11	0.00% 0	13
Program staff support	0.00% 0	0.00% 0	0.00% 0	100.00% 13	0.00% 0	13
Computing resources and support	0.00% 0	0.00% 0	7.69% 1	76.92% 10	15.38% 2	13
Housing resources and support	0.00% 0	0.00% 0	15.38% 2	69.23% 9	15.38% 2	13
A supportive and inclusive environment for all program participants	0.00% 0	0.00% 0	7.69% 1	92.31% 12	0.00% 0	13
Financial support and reimbursement process	0.00% 0	0.00% 0	38.46% 5	46.15% 6	15.38% 2	13
Online resources	0.00% 0	7.69% 1	23.08% 3	69.23% 9	0.00% 0	13

Comments included positive comments such as "*Generally, I am very happy from the support that I received. Ipam staff are excellent and very kind!*", as well as some critical comments, such as "*The room temperature was often too low.*"

The majority of participants liked collaborative opportunities they had at IPAM. The table below summarizes their responses:

	NONE	LOW	MEDIUM	HIGH	TOTAL
Collaboration within your discipline or sub-discipline.	0.00% 0	23.08% 3	23.08% 3	53.85% 7	13
Collaboration outside your discipline or sub-discipline.	0.00% 0	0.00% 0	30.77% 4	69.23% 9	13
Collaboration between junior and senior participants.	7.69% 1	7.69% 1	23.08% 3	61.54% 8	13

Almost 70% rated the possibility to collaborate outside one's discipline or sub-discipline as "high", which illustrates the highly interdisciplinary nature of this program. Almost 85% of participants responded that the possibility of collaboration between a junior and senior participant was "medium" to "high".

Most participants agreed when presented with statements about the program meeting their expectations and being of help with furthering their career and research goals. The table below summarizes these responses:

	1 - STRONGLY DISAGREE	2	3	4 - STRONGLY AGREE	TOTAL
The IPAM long program met my expectations.	0.00% 0	7.69% 1	7.69% 1	84.62% 11	13
The long program will have a positive impact on my research and career.	0.00% 0	0.00% 0	15.38% 2	84.62% 11	13
The long program was a valuable mentoring opportunity for the "junior" participants.	0.00% 0	15.38% 2	7.69% 1	76.92% 10	13
I formed new collaborations that will lead to publications or other outcomes.	0.00% 0	23.08% 3	23.08% 3	53.85% 7	13
I would participate in another IPAM long program.	0.00% 0	0.00% 0	23.08% 3	76.92% 10	13

Comments from the Long Program Participant Survey:

- The IPAM program exceed my expectations!
- Vastly exceeded my expectations
- This was really great, huge thanks to the support staff and the organizers. IPAM is an academic gem. Future long programs could be e.g. with the topics of each workshop as its own program. Maybe overall 3 workshops would have been enough but hard to say which one to cut. It was a bit busy this way.

At the completion of the program and reunion conference, we also performed several bibliographic analyses of the program. The results can be found in section K.

Comments from our reunion conference Participant Survey:

- This 1st reunion far exceeded my prior expectations. Not only great to meet them again, but also it quickly rekindled and expanded collaboration opportunities. Super-useful idea.

J. PROGRAM CONSULTANT LIST

IPAM consulted a variety of scholars and practitioners in the scientific planning of its programs. The list below includes program organizers for the programs that took place during this reporting period or upcoming programs for which organizing committees have begun meeting. The list excludes IPAM's scientific staff (directors) and members of IPAM's Science Advisory Board and Board of Trustees, who are listed in "Section N, Committee Membership". On occasion, IPAM scientific staff and Board Members are organizers of workshops and long programs, in which case they are included in the list below.

First Name	Last Name	Institution Name
Bahar	Acu	Pitzer College
Jonathan	Aurnou	University of California, Los Angeles (UCLA)
Mario	Bañuelos	Fresno State
Selenne	Bañuelos	Institute for Pure and Applied Mathematics
Ricardo	Baptista	California Institute of Technology
Matthias	Beck	San Francisco State University
Misha	Belkin	University of California, San Diego (UCSD)
Quentin	Berthet	Google
Dora	Biro	Rochester Institute of Technology
Jason	Cong	University of California, Los Angeles (UCLA)
Kevin	Corlette	The Institute for Mathematical and Statistical Innovation
Iain	Couzin	Max Planck Institute of Animal Behavior
Pranab	Das	Elon University
Eugene	De Prince	Florida State University
Rolando	de Santiago	California State University, Long Beach (CSULB)
Daniel	Erman	University of Hawaii at Manoa
Malena	Espanol	Arizona State University
Jessica	Flack	Santa Fe Institute
Cynthia	Flores	California State University, Channel Islands (CSUCI)
Stephanie	Forrest	Arizona State University
Jacob	Foster	Indiana University
Tryphon	Georgiou	University of California, Irvine (UCI)
Augusto	Gerolin	University of Ottawa and IMPA
Elizabeth	Gillaspy	University of Montana
Tom	Griffiths	Princeton University
Sumit	Gulwani	Microsoft - Redmond, WA
Boris	Hanin	Princeton University
Ben	Hayes	University of Virginia
Farnaz	Heidar-Zadeh	Queen's University
Susanne	Horn	Coventry University

First Name	Last Name	Institution Name
Eric	Hudson	University of California, Los Angeles (UCLA)
Lara	Ismert	Embry-Riddle Aeronautical University
(Keith	Julien)	University of Colorado Boulder
Selvi	Kara	Bryn Mawr College
Markos	Katsoulakis	University of Massachusetts Amherst
Max	Kleiman-Weiner	University of Washington
Rudie	Kunnen	Eindhoven University of Technology
Rongjie	Lai	Purdue University
Martha	Lewis	University of Amsterdam
Wenjing	Liao	Georgia Institute of Technology
Scott	McCalla	Montana State University - Bozeman
Govind	Menon	Brown University
Juan	Meza	University of California, Merced (UC Merced)
Leonard	Monsaingeon	Group of Mathematical Physics of the University of Lisbon (GFMUL)
Deanna	Needell	University of California, Los Angeles (UCLA)
Brent	Nelson	Michigan State University
Stanley	Osher	University of California, Los Angeles (UCLA)
Orit	Peleg	University of Colorado Boulder
Jose	Perea	Northeastern University
Kasia	Pernal	Politechnika Lodzka
Christian	Ratsch	Institute for Pure and Applied Mathematics
Richard	Ross	University of California, Los Angeles (UCLA)
Hayden	Schaeffer	University of California, Los Angeles (UCLA)
Carola	Schönlieb	University of Cambridge
Patrick	Shafto	Rutgers University-Newark
Nikhil	Srivastava	University of California, Berkeley (UC Berkeley)
Thomas	Swinburne	Centre National de la Recherche Scientifique (CNRS)
Josh	Tenenbaum	Massachusetts Institute of Technology
Dario	Trevisan	Università di Pisa
Oliver	Tse	Eindhoven University of Technology
Anthony	Várilly-Alvarado	Rice University
Andrés	Vindas Meléndez	Harvey Mudd College
Rachel	Ward	University of Texas at Austin
Birgitta	Whaley	University of California, Berkeley (UC Berkeley)
Ulrica	Wilson	Morehouse College
Yunan	Yang	Cornell University

K. PUBLICATION LIST

Bibliographic Analysis

Spring 2022 long program, Advancing Quantum Mechanics with Mathematics and Statistics

The following is a summary of bibliographic analysis of the long program Advancing Quantum Mechanics with Mathematics and Statistics, whose last activity was in December 2024. We asked program participants to tell us about published papers that they consider to be influenced by the program. These surveys are administered before the second reunion of the program, which was 2.5 years after the completion of the main part of the program.

Below is the resulting list:

1. Abbas M., et al., *Quantum probes in cancer research*, Nature Reviews Cancer **22** 2022-07-01. **Paper link:** *SCOPUS_ID:85126380591*
2. Abrahamsen N., et al., *Convergence of variational Monte Carlo simulation and scale-invariant pre-training*, Journal of Computational Physics **513** 2024-09-15. **Paper link:** *SCOPUS_ID:85195657080*
3. Adhikari S., et al., *Accurate Prediction of HSE06 Band Structures for a Diverse Set of Materials Using Δ-Learning*, Chemistry of Materials **35** 2023-10-24. **Paper link:** *SCOPUS_ID:85177063345*
4. Adil Kabylda, J Thorben Frank, Sergio Suarez Dou, Almaz Khabibrakhmanov, Leonardo Medrano Sandonas, Oliver T Unke, Stefan Chmiela, Klaus-Robert Muller, Alexandre Tkatchenko, *Molecular Simulations with a Pretrained Neural Network and Universal Pairwise Force Fields*, ChemRxiv doi:10.26434/chemrxiv-2024-bdfr0 2024. *MANUALLY_UPLOADED_ID:61*
5. Agrawal S., et al., *Photocatalytic activity of dual defect modified graphitic carbon nitride is robust to tautomerism: machine learning assisted ab initio quantum dynamics*, Nanoscale 2024-01-01. **Paper link:** *SCOPUS_ID:85190725923*
6. Agrawal S., et al., *Enhanced Charge Separation in Single Atom Cobalt Based Graphitic Carbon Nitride: Time Domain Ab Initio Analysis*, Journal of Physical Chemistry Letters **15** 2024-02-29. **Paper link:** *SCOPUS_ID:85186091170*
7. Aiello C.D., et al., *A Chirality-Based Quantum Leap*, ACS Nano **16** 2022-04-26. **Paper link:** *SCOPUS_ID:85127687428*
8. Allen A.E.A., et al., *Machine learning of material properties: Predictive and interpretable multilinear models*, Science Advances **8** 2022-05-01. **Paper link:** *SCOPUS_ID:85129949903*

9. Amaolo A., et al., *Can photonic heterostructures provably outperform single-material geometries?*, Nanophotonics **13** 2024-02-01. **Paper link:** *SCOPUS_ID:85183836107*

10. An D., et al., *Parallel transport dynamics for mixed quantum states with applications to time-dependent density functional theory*, Journal of Computational Physics **451** 2022-02-15. **Paper link:** *SCOPUS_ID:85119602419*

11. An D., et al., *Towards sharp error analysis of extended Lagrangian molecular dynamics*, Journal of Computational Physics **466** 2022-10-01. **Paper link:** *SCOPUS_ID:85133439415*

12. Anders C.J., et al., *Finding and removing Clever Hans: Using explanation methods to debug and improve deep models*, Information Fusion **77** 2022-01-01. **Paper link:** *SCOPUS_ID:85113458167*

13. Azizi K., et al., *Examining the origins of observed terahertz modes from an optically pumped atomistic model protein in aqueous solution*, PNAS Nexus **2** 2023-08-01. **Paper link:** *SCOPUS_ID:85177563514*

14. Babcock N.S., et al., *Ultraviolet Superradiance from Mega-Networks of Tryptophan in Biological Architectures*, Journal of Physical Chemistry B 2023-01-01. **Paper link:** *SCOPUS_ID:85191577118*

15. Bal G., et al., *EDGE STATE DYNAMICS ALONG CURVED INTERFACES*, SIAM Journal on Mathematical Analysis **55** 2023-01-01. **Paper link:** *SCOPUS_ID:85150931002*

16. Baldwin W.J., et al., *Dynamic Local Structure in Caesium Lead Iodide: Spatial Correlation and Transient Domains*, Small 2023-01-01. **Paper link:** *SCOPUS_ID:85171549685*

17. Bassani C.L., et al., *Nanocrystal Assemblies: Current Advances and Open Problems*, ACS Nano **18** 2024-06-11. **Paper link:** *SCOPUS_ID:85195093044*

18. Batatia I., et al., *MACE: Higher Order Equivariant Message Passing Neural Networks for Fast and Accurate Force Fields*, Advances in Neural Information Processing Systems **35** 2022-01-01. **Paper link:** *SCOPUS_ID:85163195906*

19. Ben-Abdallah P., et al., *Controlling Local Thermal States in Classical Many-Body Systems*, Physical Review Letters **129** 2022-12-23. **Paper link:** *SCOPUS_ID:85144631016*

20. Blucher S., et al., *Reconstructing Kernel-Based Machine Learning Force Fields with Superlinear Convergence*, Journal of Chemical Theory and Computation 2022-01-01. **Paper link:** *SCOPUS_ID:85159618305*

21. Cances E., et al., *SECOND-ORDER HOMOGENIZATION OF PERIODIC SCHRÖDINGER OPERATORS WITH HIGHLY OSCILLATING POTENTIALS*, SIAM Journal on Mathematical Analysis **55** 2023-01-01. **Paper link:** *SCOPUS_ID:85166177108*

22. Cances E., et al., *Simple derivation of moiré-scale continuous models for twisted bilayer graphene*, Physical Review B **107** 2023-04-15. **Paper link:** *SCOPUS_ID:85152109377*

23. Cances E., et al., *MODIFIED-OPERATOR METHOD FOR THE CALCULATION OF BAND DIAGRAMS OF CRYSTALLINE MATERIALS*, Mathematics of Computation **93** 2024-01-01. **Paper link:** *SCOPUS_ID:85187108459*

24. Ceperley D.M., et al., *Training models using forces computed by stochastic electronic structure methods*, Electronic Structure **6** 2024-03-01. **Paper link:** *SCOPUS_ID:85187957389*

25. Chao P., et al., *Physical limits in electromagnetism*, Nature Reviews Physics **4** 2022-08-*01.* **Paper link:** *SCOPUS_ID:85133247885*

26. Chao P., et al., *Fundamental Limits to Enhancing the Local Density of States Through Nanostructuring*, 2023 Conference on Lasers and Electro-Optics, CLEO 2023 2023-01-*01.* **Paper link:** *SCOPUS_ID:85176367395*

27. Chao P., et al., *Fundamental Limits to Enhancing the Local Density of States Through Nanostructuring*, CLEO: Fundamental Science, CLEO:FS 2023 2023-01-01. **Paper link:** *SCOPUS_ID:85190961481*

28. Chao P., et al., *Maximum electromagnetic local density of states via material structuring*, Nanophotonics **12** 2023-02-01. **Paper link:** *SCOPUS_ID:85142633100*

29. Cheng C., et al., *Photolysis versus Photothermolysis of N2O on a Semiconductor Surface Revealed by Nonadiabatic Molecular Dynamics*, Journal of the American Chemical Society **145** 2023-01-11. **Paper link:** *SCOPUS_ID:85146140102*

30. Chmiela S., et al., *Accurate global machine learning force fields for molecules with hundreds of atoms*, Science Advances **9** 2023-01-13. **Paper link:** *SCOPUS_ID:85146140799*

31. Chormai P., et al., *Disentangled Explanations of Neural Network Predictions by Finding Relevant Subspaces*, IEEE Transactions on Pattern Analysis and Machine Intelligence 2024-01-01. **Paper link:** *SCOPUS_ID:85190320181*

32. Chu W., et al., *Ultrafast charge transfer coupled to quantum proton motion at molecule/metal oxide interface*, Science Advances **8** 2022-06-01. **Paper link:** *SCOPUS_ID:85132454514*

33. Dai D., et al., *Impact of large A-site cations on electron-vibrational interactions in 2D halide perovskites: Ab initio quantum dynamics*, Journal of Chemical Physics **160** 2024-03-21. **Paper link:** *SCOPUS_ID:85188498200*

34. De A., et al., *Tunneling-Driven Marcus-Inverted Triplet Energy Transfer in a Two-Dimensional Perovskite*, Journal of the American Chemical Society **146** 2024-02-14. **Paper link:** *SCOPUS_ID:85184599252*

35. Defo R.K., et al., *Charge-state stability of color centers in wide band gap semiconductors*, Physical Review B **108** 2023-12-15. **Paper link:** *SCOPUS_ID:85181033920*

36. Dombrowski A.-K., et al., *Towards robust explanations for deep neural networks*, Pattern Recognition **121** 2022-01-01. **Paper link:** *SCOPUS_ID:85112531912*

37. Dombrowski A.-K., et al., *Diffeomorphic Counterfactuals With Generative Models*, IEEE Transactions on Pattern Analysis and Machine Intelligence **46** 2024-05-01. **Paper link:** *SCOPUS_ID:85179788388*

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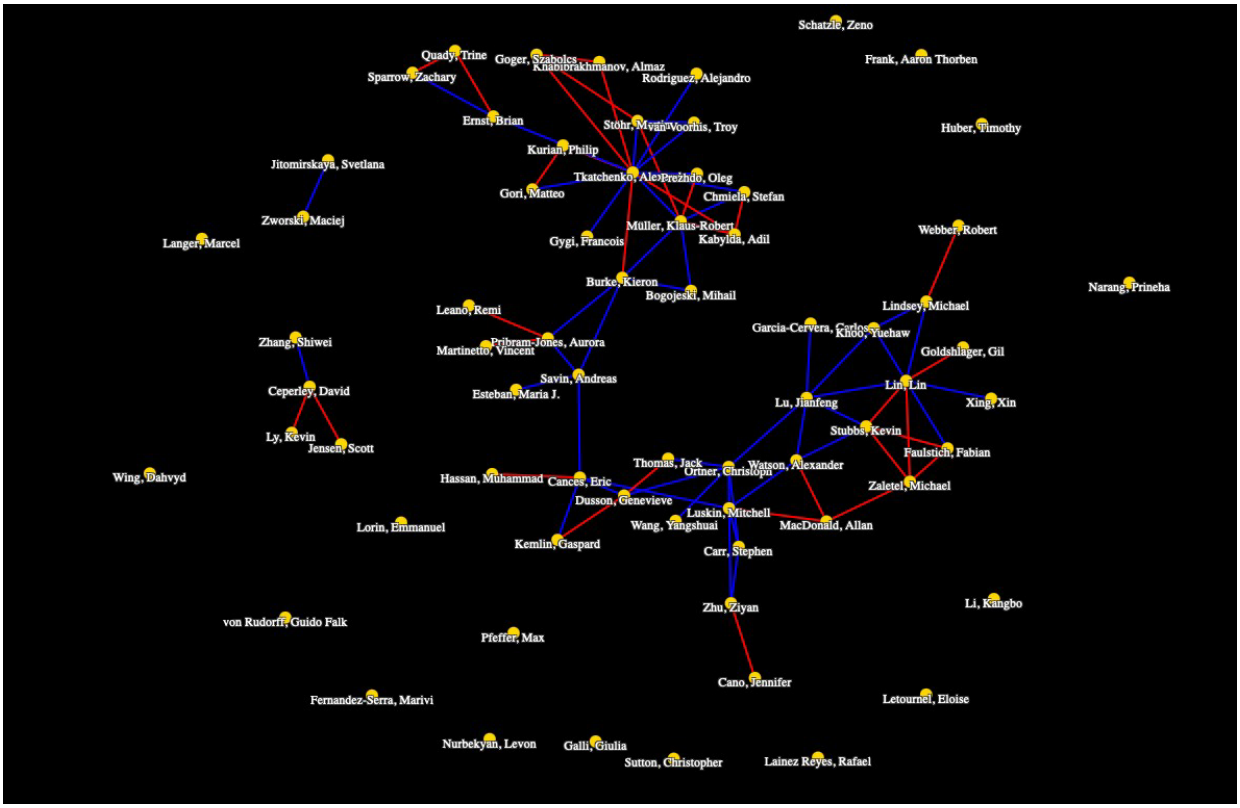
Collaboration network analysis

In addition, we have performed an automated collaboration analysis, seeking to identify pairs of collaborators that have not worked with each other prior to the program. In the graph below, such pairs are marked with red edges, while authors that collaborated prior to the year of the program are joined with blue edges.



It is evident that many noteworthy new collaborations were formed as a result of this program.

Bibliographic Analysis

Fall 2022 long program, Computational Microscopy

The following is a summary of bibliographic analysis of the long program Advancing Quantum Mechanics with Mathematics and Statistics, whose last activity was in June 2025. We asked program participants to tell us about published papers that they consider to be influenced by the program. These surveys are administered before the second reunion of the program, which was 2.5 years after the completion of the main part of the program.

Below is the resulting list:

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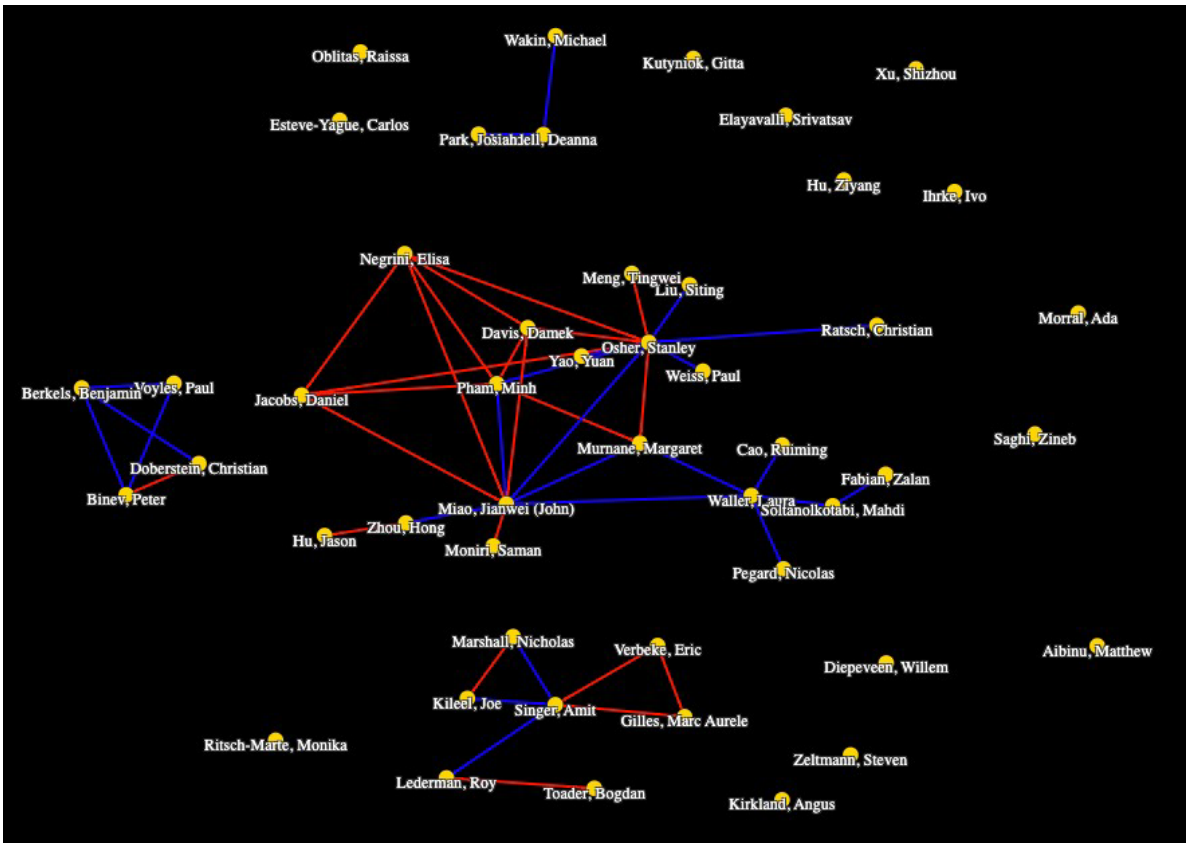
Collaboration network analysis

In addition, we performed an automated collaboration analysis, seeking to identify pairs of collaborators that have not worked with each other prior to the program. In the graph below, such pairs are marked with red edges, while authors that collaborated prior to the year of the program are joined with blue edges.



The program was successful in both bringing several new researchers to existing collaboration clusters, as well as forming collaborations that join clusters of previously collaborating authors.

L. INDUSTRIAL AND GOVERNMENTAL INVOLVEMENT

We have significant involvement of industry and government labs in our summer program, Research in Industrial Projects for Students (RIPS)-Los Angeles. Companies and other organizations sponsor research projects and one or more representatives of the organization interact with the student team. Many of them are listed as participants of RIPS and RIPS Projects Day. Additionally, significant numbers of industry and government participants took part in our long programs and workshops; the table below lists workshops, programs, and summer schools with 4 or more industry participants.

Workshop Name	Industry Participants
Groundwork for Operator Algebras Lecture Series	14
Long Program: Mathematics of Intelligences	5
Workshop I: Analyzing High-dimensional Traces of Intelligent Behavior	5
Workshop II: Theory and Practice of Deep Learning	10
Workshop III: Naturalistic Approaches to Artificial Intelligence	8
Workshop IV: Modeling Multi-Scale Collective Intelligences	5
Winter School: Quantum Error Suppression, Mitigation, and Correction	5
LatMath 2025	5

We seek the advice of government and industry by recruiting corporate and government leaders to serve on our Science Advisory Board and Board of Trustees. See section N for a complete list of members and their affiliations.

There were 118 participants that identified as being from Government or Industry. Of these, 28 unique participants were organizers or speakers.

Of these, 3 unique participants came from government or military institutions, including: Sandia National Laboratory, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory.

There were 47 unique participants from companies such as Aerospace Corporation, Advanced Micro Devices, Amazon Research, Analog Devices, Google, Good DeepMind, Google Quantum AI, IBM Research, Meta, Microsoft Research, Southwest Research Institute, and Quantinuum, who served as speakers or organizers.

M. EXTERNAL SUPPORT

In addition to the funding listed in Table M below, IPAM receives substantial in-kind financial support from UCLA. The Director's entire salary/benefits and administrative stipend are paid directly by UCLA. The Director of Special Projects is released from two courses at the cost of replacing him by a junior person academic. IPAM is not charged for the use of its centrally located building, maintenance, or custodial care. Also, UCLA offers IPAM centralized administrative support, technology, recreational facilities, and access to renown libraries, though it is difficult to quantify such support monetarily.

IPAM received gifts towards its endowment and current use funds from several donors, including Aerospace ($30K), Lawrence Livermore National Laboratory ($30K), and Analog Devices ($100K). As of March 31, 2025 (the last date for which figures are available), IPAM's total endowment stood at $4,218,356. The endowment is designed to generate approximately 4% per year in income.

The table shows other funding received by IPAM from April 1, 2024 through March 31, 2025.

Table M: Other Funding Support	**2024-2025**
UCLA Funding	
Dean Physical Sciences	$98,812
Vice Chancellor for Research	$155,252
Sub-total	$254,064
Endowments and Current Gifts	
Endowments – New Gifts & Investment Income	$218,851
New Current Use Gift Funds	$238,695
Sub-total	$457,546
TOTAL	**$711,610**

N. COMMITTEE MEMBERSHIP

IPAM's committees include the Board of Trustees and Science Advisory Board. The members during the reporting period are listed below. The IPAM directors are ex officio members.

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Science Advisory Board, 2024-2025

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Ryan Tibshirani	UC Berkeley	Professor in the Departments of Statistics and Machine Learning
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