Annual Report 2023-24

NSF Award DMS-1929348
Covering activity between June 1, 2023 and May 31, 2024

Contents

1. Overview

This is the 2023-24 annual report for the Institute for Mathematical and Statistical Innovation, funded by NSF grant DMS-1929348. It covers activities of the Institute which took place between June 1, 2023 and May 31, 2024.

The Institute for Mathematical and Statistical Innovation (IMSI) is a mathematical sciences research institute hosted by the University of Chicago, and operated in partnership with Northwestern University, the University of Illinois at Chicago, and the University of Illinois at Urbana-Champaign.

1.1 Mission

The mission of IMSI is to bring rigorous mathematics and statistics to bear on complex urgent problems of significant scientific and social importance, and to spur transformational change in the mathematical sciences and the mathematical sciences community. There are three primary pillars to this mission: scientific activity, a focus on diversity and broadening participation in the mathematical sciences, and a focus on effective communication about mathematical science research to a variety of audiences.

IMSI is committed to first-rate interdisciplinary research in areas of great societal interest and impact where the mathematical sciences have the potential to contribute. It aims to make a difference in ways that are scientifically and socially important. The institute will focus the bulk of its scientific activity during the period of the current grant on six themes: Climate and Sustainability, Data and Information, Health and Medical Care, Materials Science, Quantum Computing and Information, and Uncertainty Quantification. These areas embody significant challenges for society at large, and meaningful progress in these areas will in many cases require engagement from researchers and decision makers across a variety of sectors, including academia, national labs, government, and the private sector, and will highlight the important and expanding role played by the mathematical sciences across these sectors.

A crucial factor in addressing these scientific challenges is the diversity of those engaged in research and activity at IMSI. The challenges with which we intend to engage will require perspectives and insight from a number of directions in order to make progress. As suggested above, these insights and perspectives must emerge from interactions among researchers from multiple disciplines and employment sectors. At the same time, there is often a need for research to usefully inform policy and decision making, which requires expanding conversation and engagement beyond the realm of basic research. Moreover, the broad social impacts of these challenges implies that effective engagement with them will often require the participation of a community of researchers who can collectively bring an understanding of how these challenges are experienced across human society as a whole. This points to a need for broad participation in the mathematical sciences.

The third pillar in IMSI's mission is an emphasis on effective communication and, beyond that, effective collaboration and engagement. An important aspect of scientific progress is that the insights it generates must propagate and land with those who can make effective use of them. This often requires communicating and collaborating across differences arising from boundaries between intellectual disciplines, research cultures, employment sectors and roles, career and education stages, positions in society, and more. Scientific research often defaults to a mode of experts speaking to experts who emerge from similar research cultures. IMSI aims to encourage scientific research that does not remain confined to this mode, and to provide ways for researchers in the mathematical sciences to build skills in communicating across differences.

1.2 Overview of the Year

IMSI hosted two long program this year: Algebraic Statistics and Our Changing World (September 18-December 15, 2023) and Data-Driven Materials Informatics (May 4-May 24, 2024). In addition, IMSI hosted or co-sponsored eight topical research workshops and one summer school outside the framework of the two long programs, and two interdisciplinary research clusters. IMSI also sponsored a number of events aimed at broadening participation and workforce development, including the BRING MATH conference in collaboration with Argonne National Laboratory, the Modern Math Workshop in Portland, Oregon (part of the MSIDI initiative), the Career Paths in the Mathematical Sciences workshop organized in collaboration with the Math Alliance and the Institute for Mathematics and its Applications, as well as the Summer Mathematics and Statistics Accelerator (SUMSA) and a summer internship program for Ph.D. students in mathematics and statistics.

2. Participant Demographics

2.1 List of Activities

IMSI Activities 2023-2024

Title	Type of Activity	Dates
Career Paths in the Mathematical Sciences	Special Event	June 8-9, 2023
IMSI Summer Internship Program	Internship	June 10 – August 16, 2023
Summer Undergraduate Mathematics and Statistics Accelerator (SUMSA)	SUMSA	June 12 – August 4, 2023
Climate Tipping Phenomena in Non-autonomous Paleoecosystems (Interdisciplinary Research Cluster)	Short Research Event	June 20-30, 2023
Laplacian Growth Models: Theory and Applications	Short Research	June 26-30, 2023

	Event	
Object Oriented Data Analysis in Health Sciences	Short Research Event	July 10-14, 2023
AI+Science Summer School	Short Research Event	July 17-21, 2023
Permutation and Causal Inference: Connections and Applications	Short Research Event	August 22-25, 2023
Algebraic Statistics and Our Changing World	Long Program	September 18 – December 15, 2023
Invitation to Algebraic Statistics and Applications	Short Research Event	September 18-22, 2023
Apprenticeship Week: Varieties from Statistics	Short Research Event	October 2-6, 2023
BRING MATH: Bridges for the Next Generation: Mathematical Science Research and Our Future	Special Event	Oct 5-6, 2023
Algebraic Statistics for Ecological and Biological Systems	Short Research Event	October 9-13, 2023
Modern Mathematics Workshop	Special Event	October 25-26, 2023
Algebraic Economics	Short Research Event	November 6-10, 2023
Bayesian Statistics and Statistical Learning: New Directions in Algebraic Statistics	Short Research Event	December 11-15, 2023
Teaching and Evaluating Data Communication at Scale	Short Research Event	January 10-12, 2024
Decision Making and Uncertainty	Short Research Event	February 5-9, 2024
Computational Challenges and Optimization in Kinetic Plasma Physics	Short Research Event	February 19-22, 2024
Methods for Solving and Analyzing Dynamic Models in the Face of Uncertainty and Cross-sectional Heterogeneity	Short Research Event	March 7-8, 2024
Data-Driven Materials Informatics	Long Program	March 4 – May 24, 2024
Materials Informatics: Tutorials and Hands-on	Short Research Event	March 11-15, 2024
Machine Learning in Electronic-Structure Theory	Short Research	March 25-29, 2024

	Event	
Machine Learning Force Fields	Short Research Event	April 8-12, 2024
Learning Collective Variables and Coarse Grained Models	Short Research Event	April 22-26, 2024
New Approaches to Ecological Dynamics of Microbial Communities	Short Research Event	April 29 – May 3, 2024
Data Sciences for Mesoscale and Macroscale Materials Models	Short Research Event	May 13-17, 2024
Co-Creating a Community Data Visualization Tool with Community Partners (Interdisciplinary Research Cluster)	Short Research Event	May 20-31, 2024

2.2 Demographics by Type of Activity

Demographics by Activity

Activity		Long Programs '23-'24	Short Research Events '23-'24	Special Events '23-'24	SUMSA '23	Internship '23
Total Number of Participants (Includes all participants, speakers, and organizers)		89	1261	191	25	6
Gender	Female	29	369	84	11	3
	Male	53	835	92	14	3
	Nonbinary	2	11	9	0	0
	I identify as: _____	0	0	1	0	0
	Prefer not to self-identify	4	39	4	0	0
	Unknown	1	9	4	0	0

*Participants were able to indicate more than one gender. Those who selected multiple genders are represented in the totals more than once.

Activity		Long Programs '23-'24	Short Research Events '23-'24	Special Events '23-'24	SUMSA '23	Internship '23
Total Number of Participants (Includes all participants, speakers, and organizers)		89	1261	191	25	6
Race	American Indian or Alaskan Native	0	10	6	0	0
	Asian	19	447	24	7	3
	Black or African American	4	50	33	1	0
	Native Hawaiian or Other Pacific Islander	0	0	4	1	0
	White	56	613	88	17	3
	Do Not Wish to Provide	9	149	39	1	0
	Unknown	1	10	11	0	0

*Participants were able to indicate more than one race. Those who selected multiple races are represented in the totals more than once.

Activity		Long Programs '23-'24	Short Research Events '23-'24	Special Events '23-'24	SUMSA '23	Internship '23
Total Number of Participants (Includes all participants, speakers, and organizers)		89	1261	191	25	6
Ethnicity	Hispanic or Latino	6	90	93	3	0
	Not Hispanic or Latino	76	1000	85	19	5
	Do not wish to provide	7	163	5	3	1
	Unknown	0	8	8	0	0

Activity		Long Programs '23-'24	Short Research Events '23-'24	Special Events '23-'24	SUMSA '23	Internship '23
Total Number of Participants (Includes all participants, speakers, and organizers)		89	1261	191	25	6
Employment/Educational Status	Faculty Member or Academic Administrator	44	511	38	0	0
	Graduate Student	24	456	30	0	6
	Non-academic Employment	2	67	12	0	0
	Postdoctoral Associate	18	195	3	0	0
	Retired / Not Employed / Self-employed	1	9	3	0	0
	Undergraduate Student	0	22	105	25	0
	High School Student	0	1	0	0	0
	Unknown	0	0	0	0	0

Activity		Long Programs '23-'24	Short Research Events '23-'24	Special Events '23-'24	SUMSA '23	Internship '23
Total Number of Participants (Includes all participants, speakers, and organizers)		89	1261	191	25	6
Field(s) of Expertise*	Mathematics	60	553	162	24	4
	Statistics	33	360	45	9	2
	Physics / Astronomy	4	137	6	0	0
	Chemistry	6	161	3	1	0
	Materials Science	14	179	1	0	0
	Computer Science / Information Science	7	151	23	3	0
	Engineering	1	80	3	0	0
	Life Sciences	2	51	3	1	0
	Medicine	0	9	1	0	0
	Geosciences	0	8	2	0	0
	Economics	0	15	2	0	0
	Social Sciences	0	7	2	0	0
	Education or Learning Research	1	15	5	0	0
	Other	2	93	7	0	0

*Participants were able to indicate more than one field of expertise. Those that selected multiple fields of expertise are represented in the totals more than once.

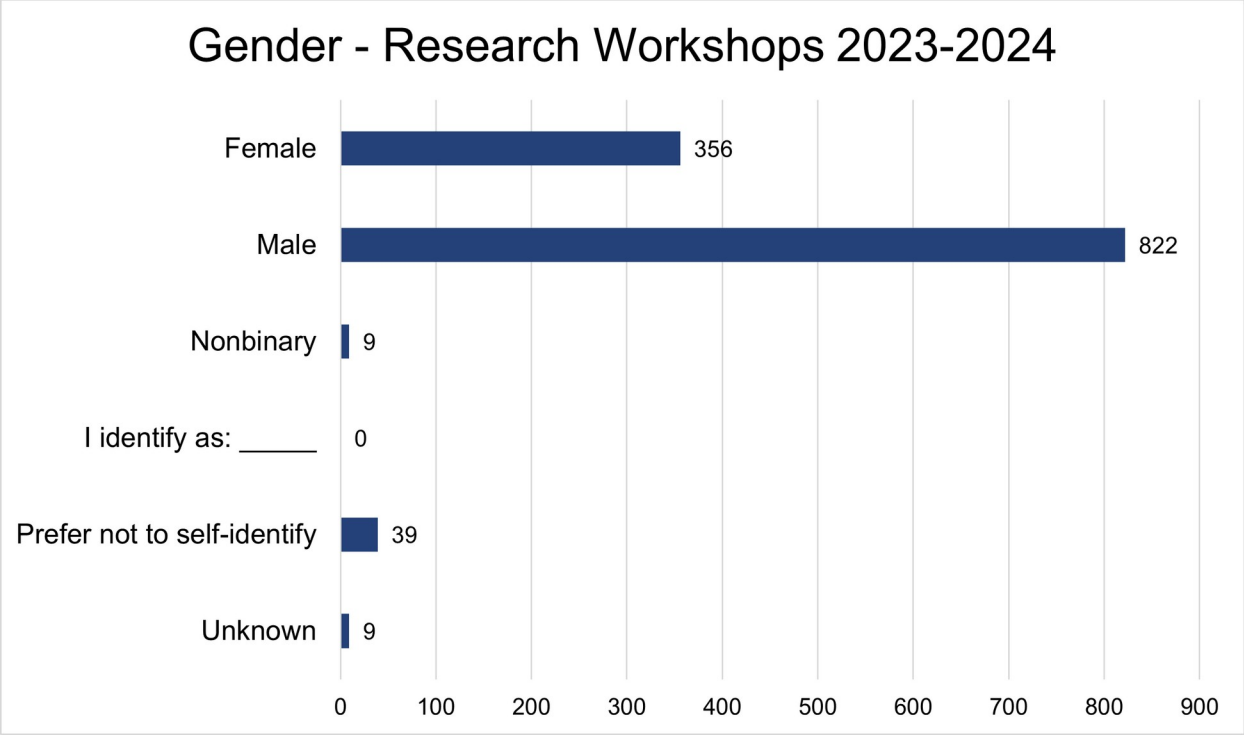
2.3 Demographics for Research Workshops

The following demographic information includes participants, organizers, speakers, facilitators, and panelists. Some individuals may be reflected more than one time if they participated in more than one workshop. This category of activity includes the following events:

- Laplacian Growth Models: Theory and Applications
- Object Oriented Data Analysis in Health Sciences
- Permutation and Causal Inference: Connections and Applications
- Invitation to Algebraic Statistics and Applications
- Apprenticeship Week: Varieties from Statistics
- Algebraic Statistics for Ecological and Biological Systems
- Algebraic Economics
- Bayesian Statistics and Statistical Learning: New Directions in Algebraic Statistics

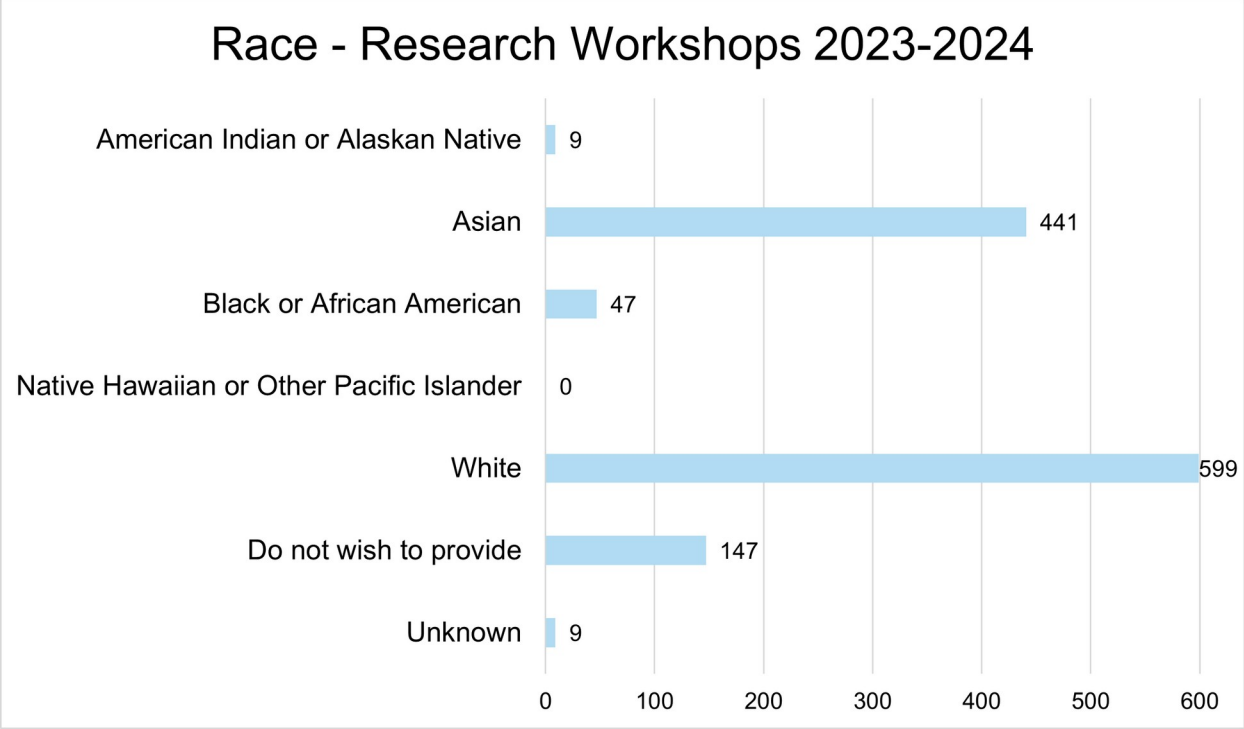
- Teaching and Evaluating Data Communication at Scale
- Decision Making and Uncertainty
- Computational Challenges and Optimization in Kinetic Plasma Physics
- Methods for Solving and Analyzing Dynamic Models in the Face of Uncertainty and Cross-sectional Heterogeneity
- Materials Informatics: Tutorials and Hands-on
- Machine Learning in Electronic-Structure Theory
- Machine Learning Force Fields
- Learning Collective Variables and Coarse Grained Models
- Data Sciences for Mesoscale and Macroscale Materials Models

Research Workshops 2023-2024 - Participants by Gender



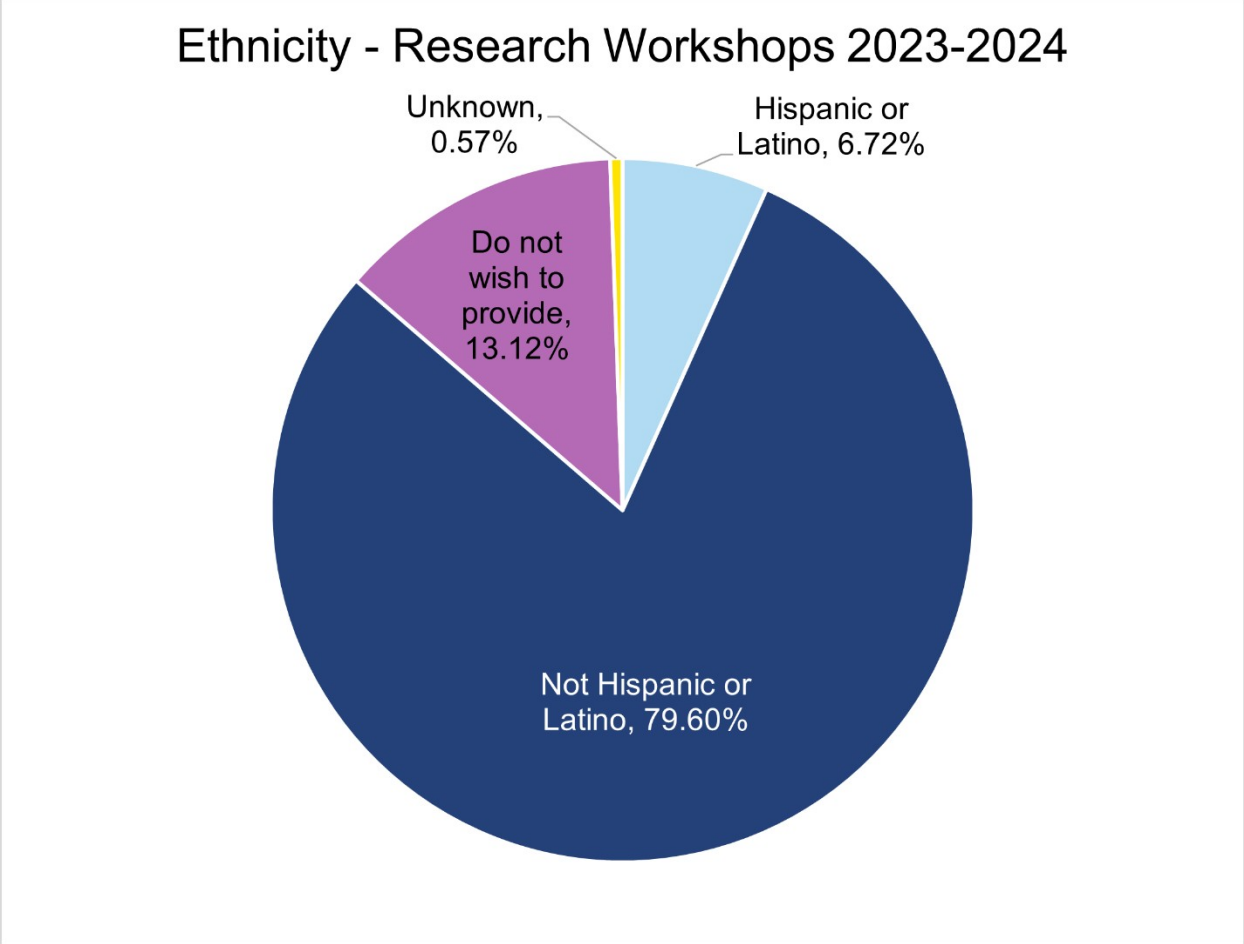
Note: Participants could select multiple genders. Some individuals may be reflected in this chart more than once.

Research Workshops 2023-2024 - Participants by Race

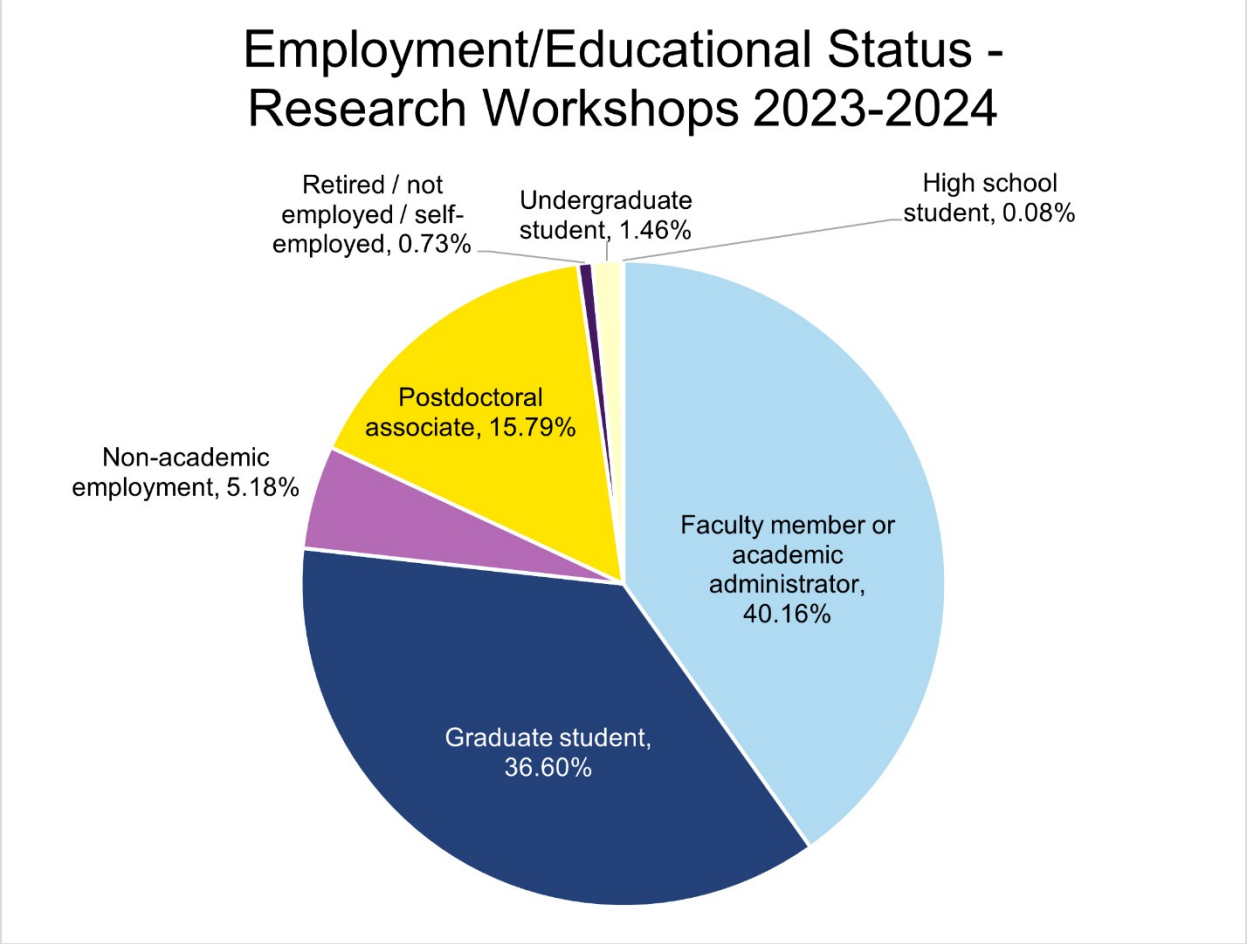


Note: Participants could select multiple races. Some individuals may be reflected in this chart more than once.

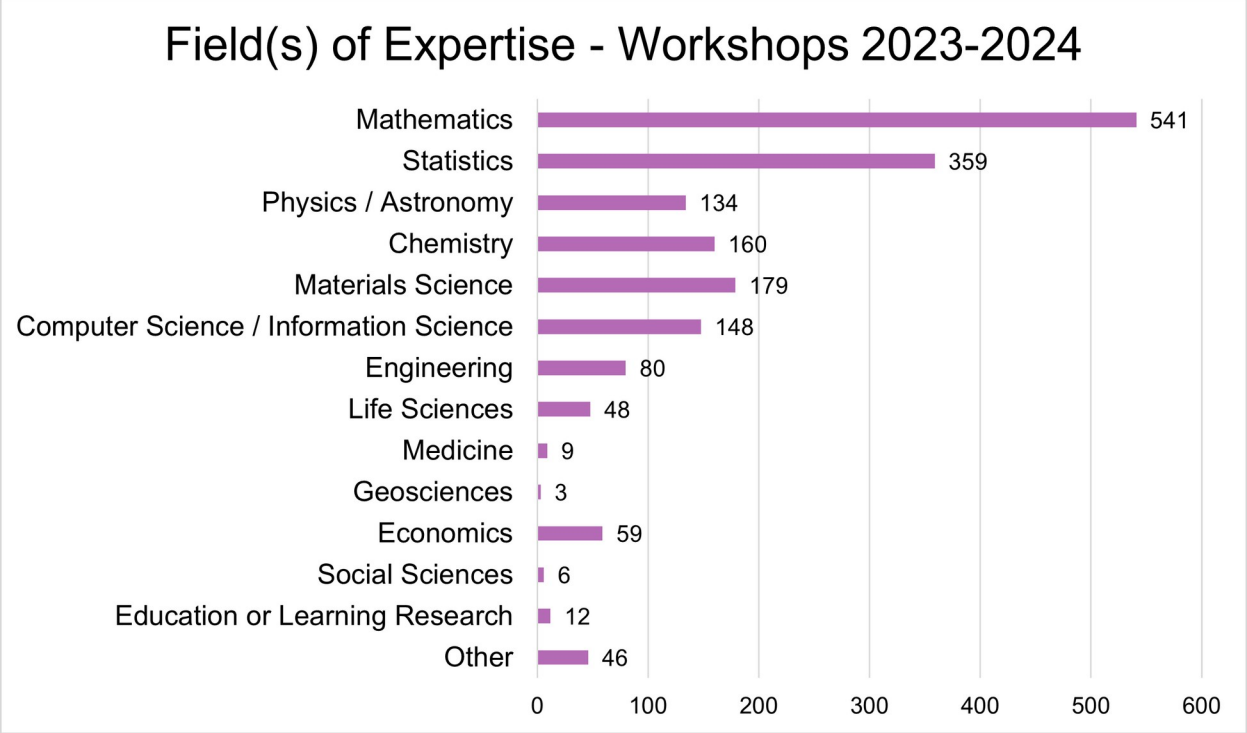
Research Workshops 2023-2024 - Participants by Ethnicity



Workshops 2023-2024 - Participants by Employment/Educational Status

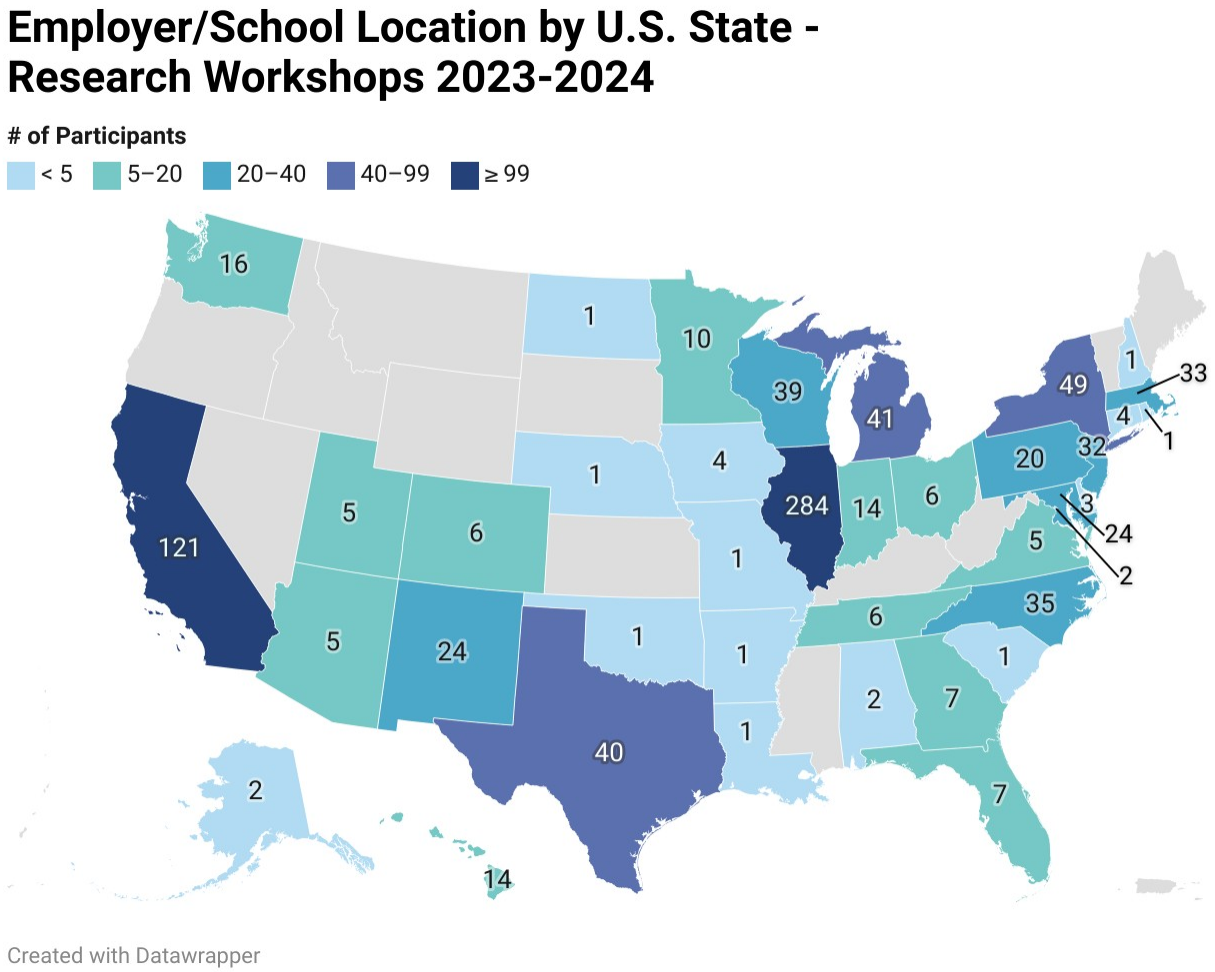


Research Workshops 2023-2024 - Participants by Field(s) of Expertise



Note: Participants were able to indicate more than one field of expertise. Those that selected multiple fields of expertise are represented in the totals more than once.

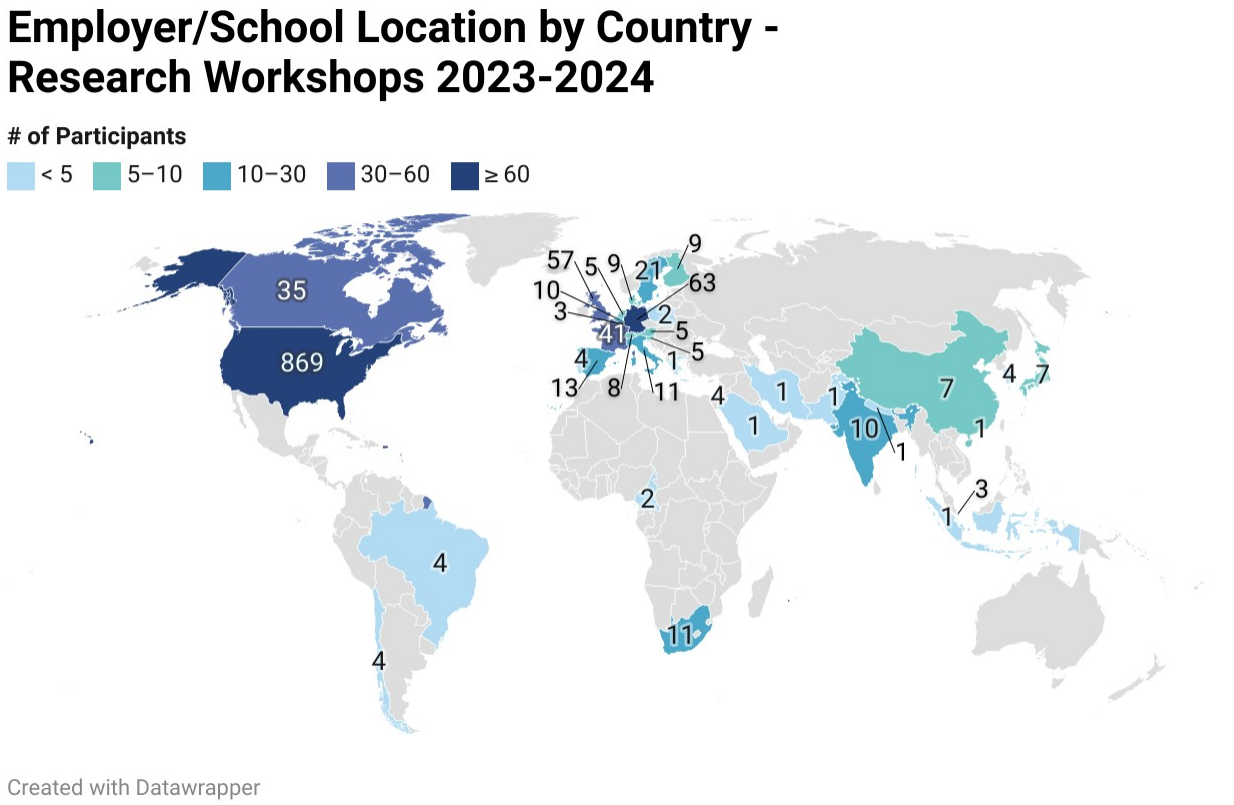
Research Workshops 2023-2024 - Participants by Employer/School Location (United States)



Research Workshops 2023-2024 - Participants by Employer/School Location (United States)			
State	Number of Participants	State	Number of Participants
Alabama	2	Montana	0
Alaska	2	Nebraska	1
Arizona	5	Nevada	0
Arkansas	1	New Hampshire	1
California	121	New Jersey	32
Colorado	6	New Mexico	24
Connecticut	4	New York	49
Delaware	3	North Carolina	35

District of Columbia	2	North Dakota	1
Florida	7	Ohio	6
Georgia	7	Oklahoma	1
Hawaii	14	Oregon	0
Idaho	0	Pennsylvania	20
Illinois	284	Puerto Rico	0
Indiana	14	Rhode Island	1
Iowa	4	South Carolina	1
Kansas	0	South Dakota	0
Kentucky	0	Tennessee	6
Louisiana	1	Texas	40
Maine	0	Utah	5
Maryland	24	Vermont	0
Massachusetts	33	Virginia	5
Michigan	41	Washington	16
Minnesota	10	West Virginia	0
Mississippi	0	Wisconsin	39
Missouri	1	Wyoming	0

Research Workshops 2023-2024 - Participants by Employer/School Location (Country)



Research Workshops 2023-2024 - Participants by Employer/School Location			
Country	Number of Participants	Country	Number of Participants
Australia	2	Italy	11
Austria	5	Japan	7
Belgium	10	South Korea	4
Brazil	4	Luxembourg	3
Cameroon	2	Nepal	1
Canada	35	Netherlands	5
Chile	4	Pakistan	1
China	7	Poland	2
Denmark	9	Portugal	4
Finland	9	Saudi Arabia	1

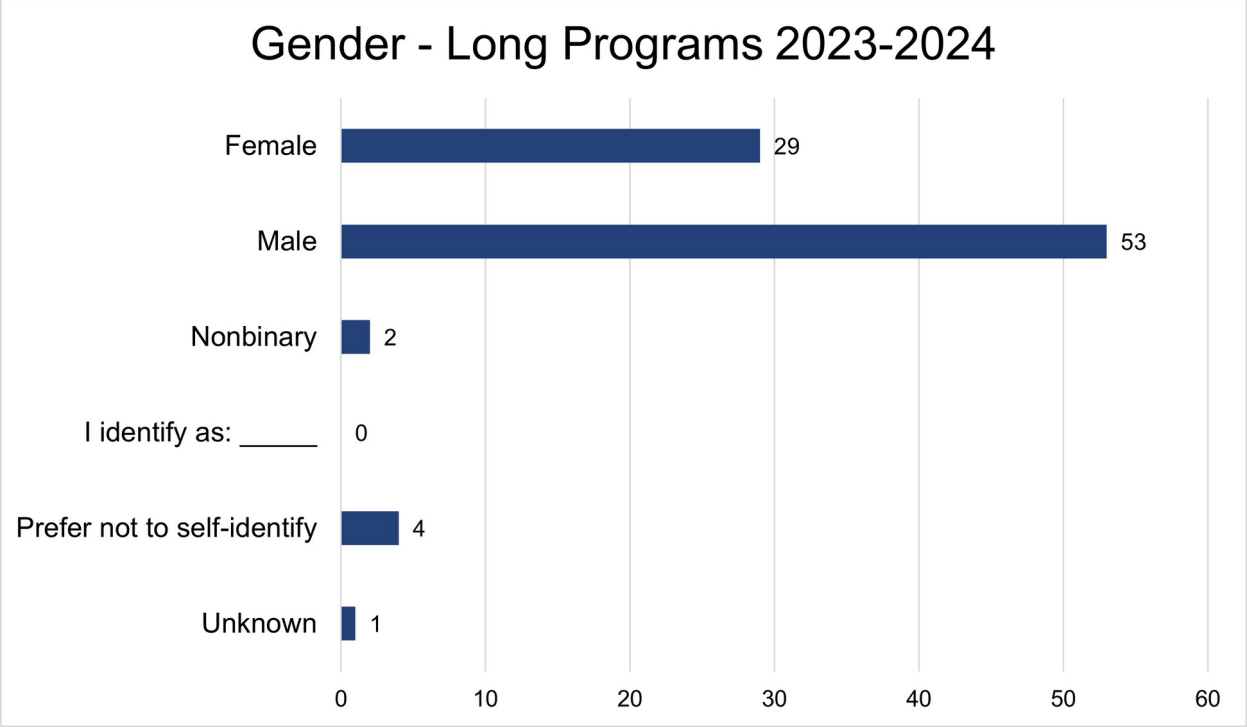
France	41	Singapore	3
Germany	63	Slovenia	5
Greece	1	South Africa	11
Hong Kong	1	Spain	13
India	10	Sweden	21
Indonesia	1	Switzerland	8
Iran	1	United Kingdom	57
Israel	4	United States of America	869

2.4 Demographics for Long Programs

The following demographic information includes research members who were in residence during a long program.

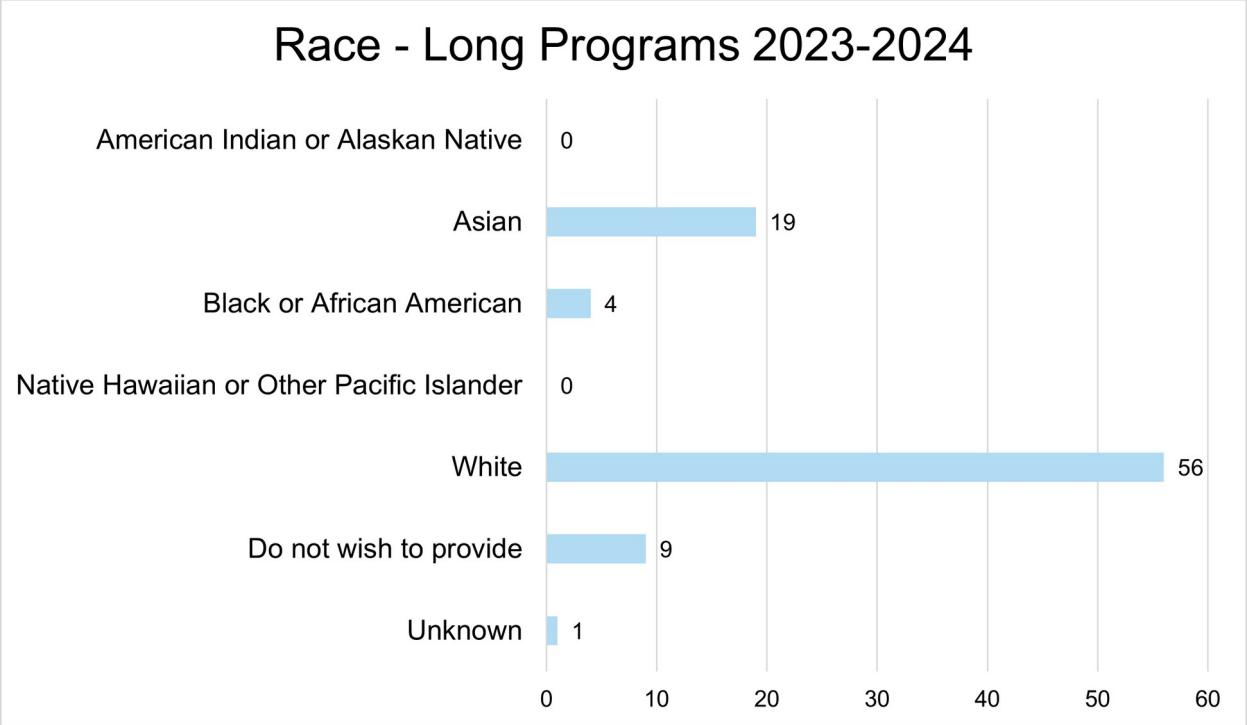
- Fall 2023: Algebraic Statistics and Our Changing World: New Methods for New Challenges
- Spring 2024: Data-Driven Materials Informatics: Statistical Methods and Mathematical Analysis

Long Programs 2023-2024 - Participants by Gender



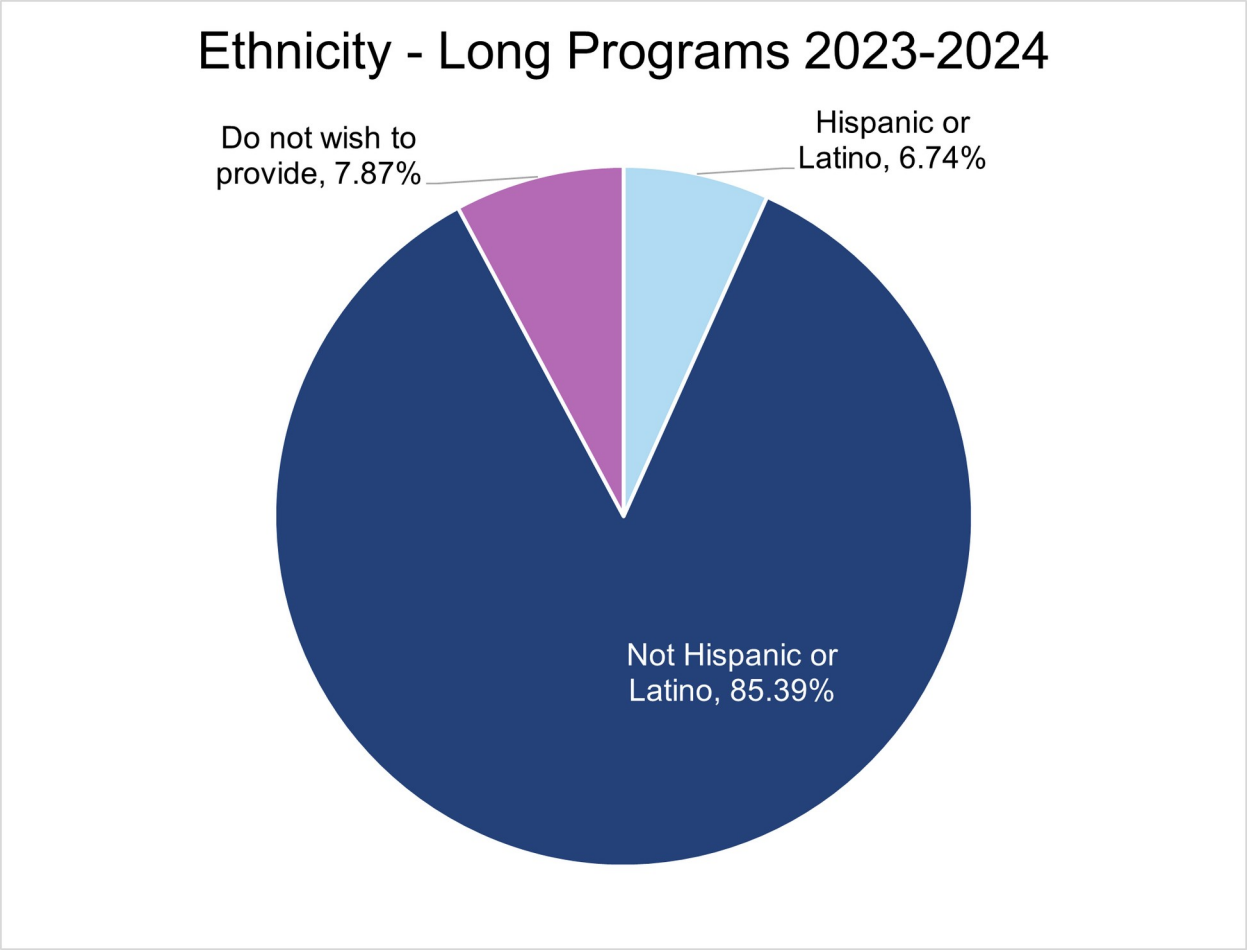
Note: Participants could select multiple genders. Some individuals may be reflected in this chart more than once.

Long Programs 2023-2024 - Participants by Race

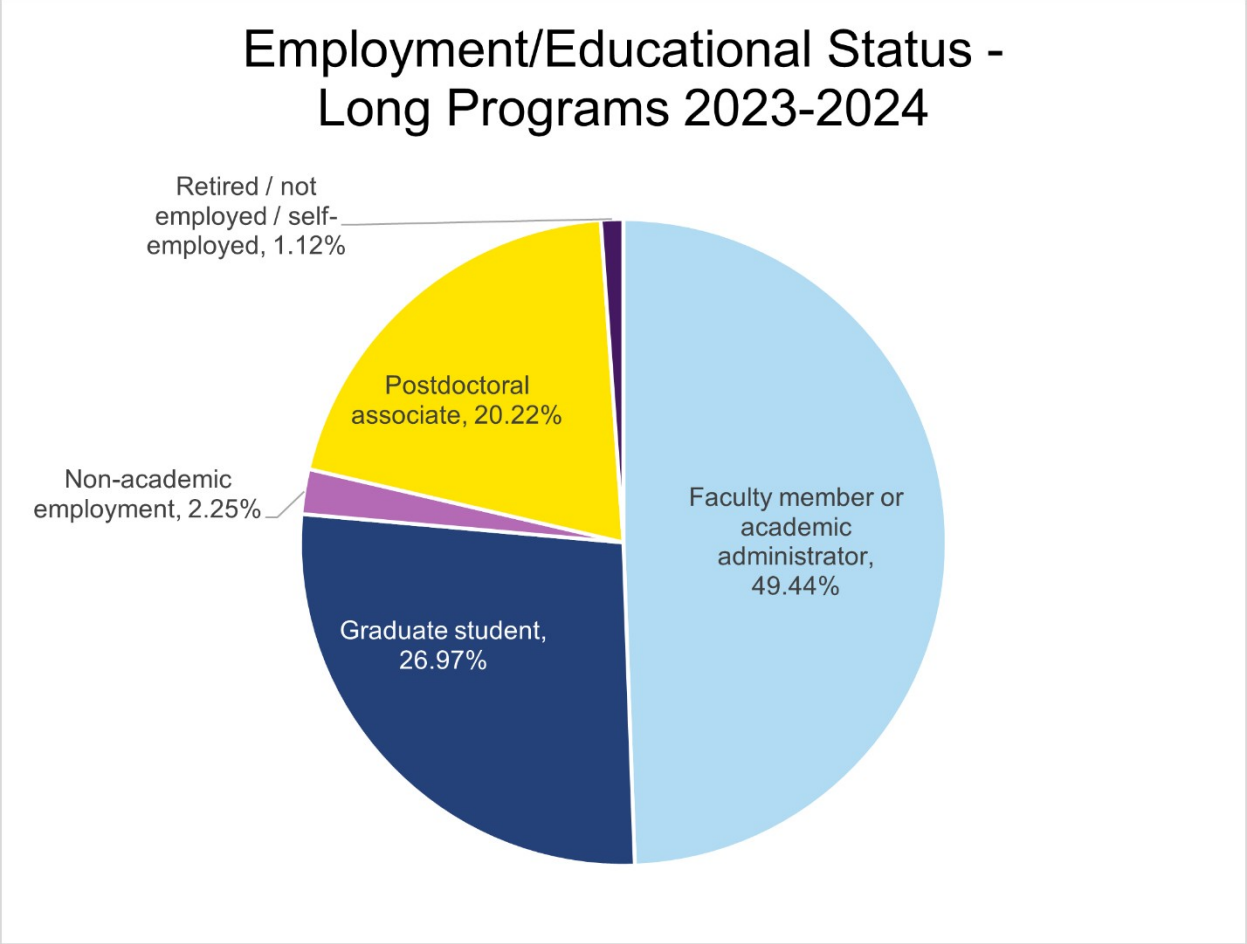


Note: Participants could select multiple races. Some individuals may be reflected in this chart more than once.

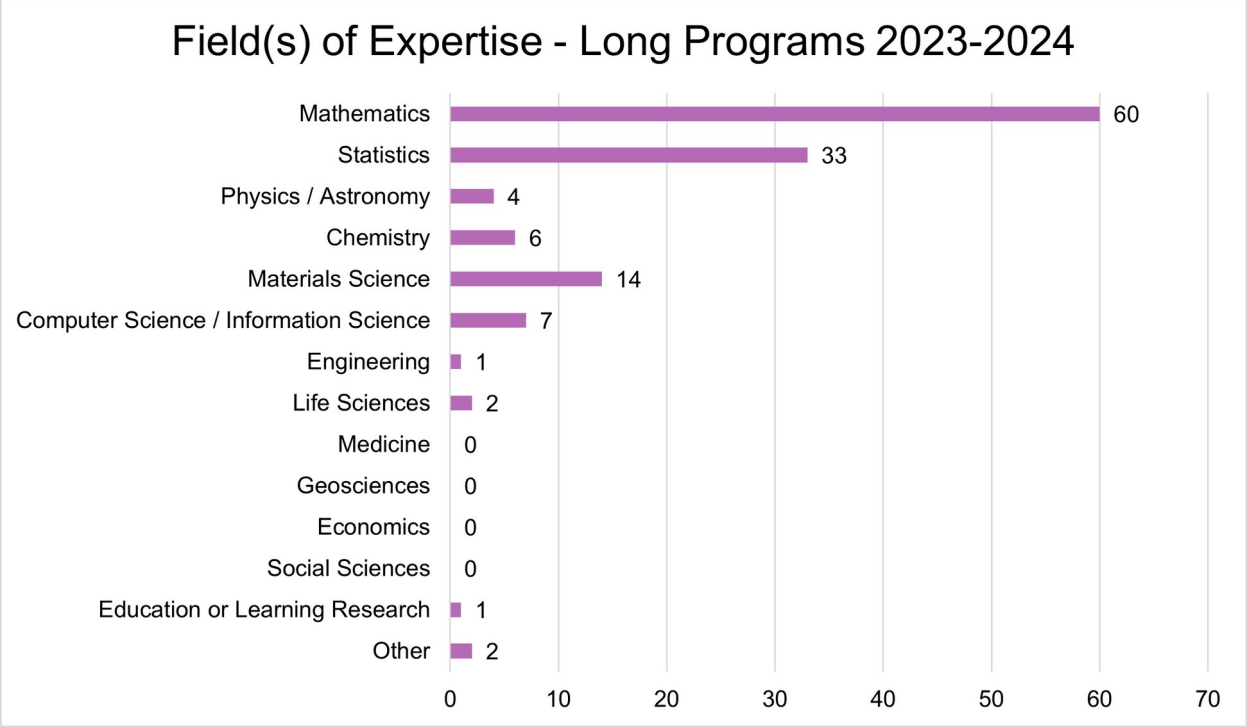
Long Programs 2023-2024 - Participants by Ethnicity



Programs 2023-2024 - Participants by Employment/Educational Status

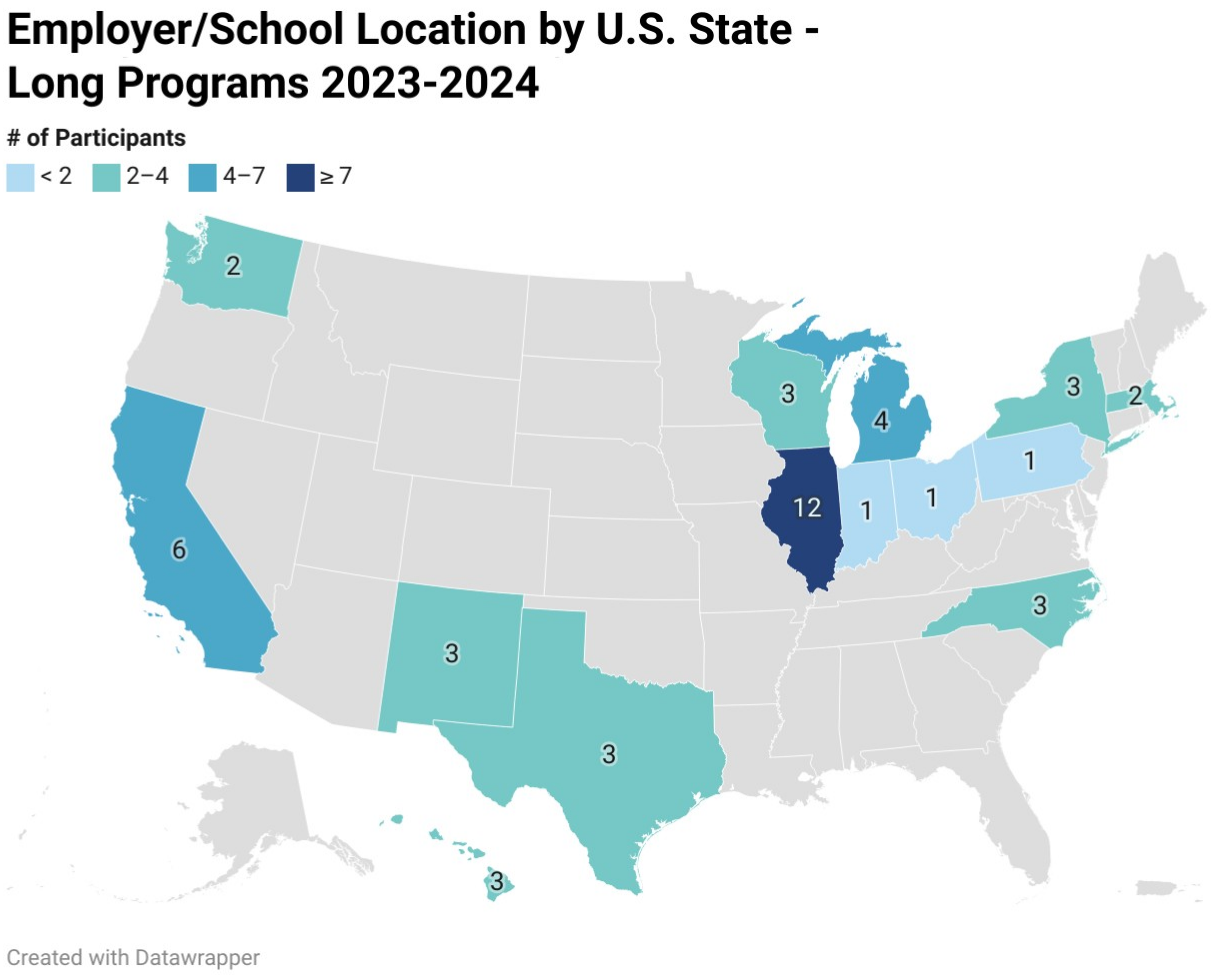


Long Programs 2023-2024 - Participants by Field(s) of Expertise



Note: Participants were able to indicate more than one field of expertise. Those that selected multiple fields of expertise are represented in the totals more than once.

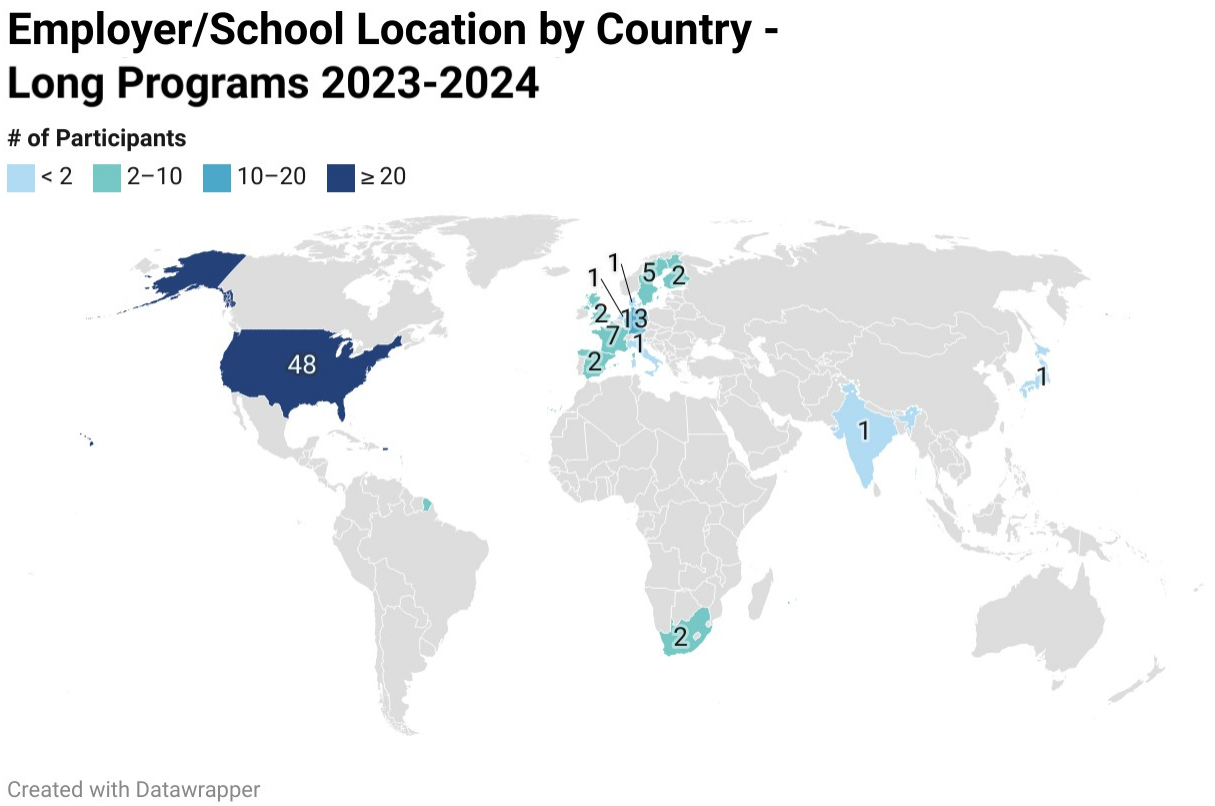
Programs 2023-2024 - Participants by Employer/School Location (United States)



Long Programs 2023-2024 - Participants by Employer/School Location (United States)			
State	Number of Participants	State	Number of Participants
Alabama	0	Montana	0
Alaska	1	Nebraska	0
Arizona	0	Nevada	0
Arkansas	0	New Hampshire	0
California	6	New Jersey	0
Colorado	0	New Mexico	3
Connecticut	0	New York	3
Delaware	0	North Carolina	3
District of Columbia	0	North Dakota	0

Florida	0	Ohio	1
Georgia	0	Oklahoma	0
Hawaii	3	Oregon	0
Idaho	0	Pennsylvania	1
Illinois	12	Puerto Rico	0
Indiana	1	Rhode Island	0
Iowa	0	South Carolina	0
Kansas	0	South Dakota	0
Kentucky	0	Tennessee	0
Louisiana	0	Texas	3
Maine	0	Utah	0
Maryland	0	Vermont	0
Massachusetts	2	Virginia	0
Michigan	4	Washington	2
Minnesota	0	West Virginia	0
Mississippi	0	Wisconsin	3
Missouri	0	Wyoming	0

Long Programs 2023-2024 - Participants by Employer/School Location (Country)



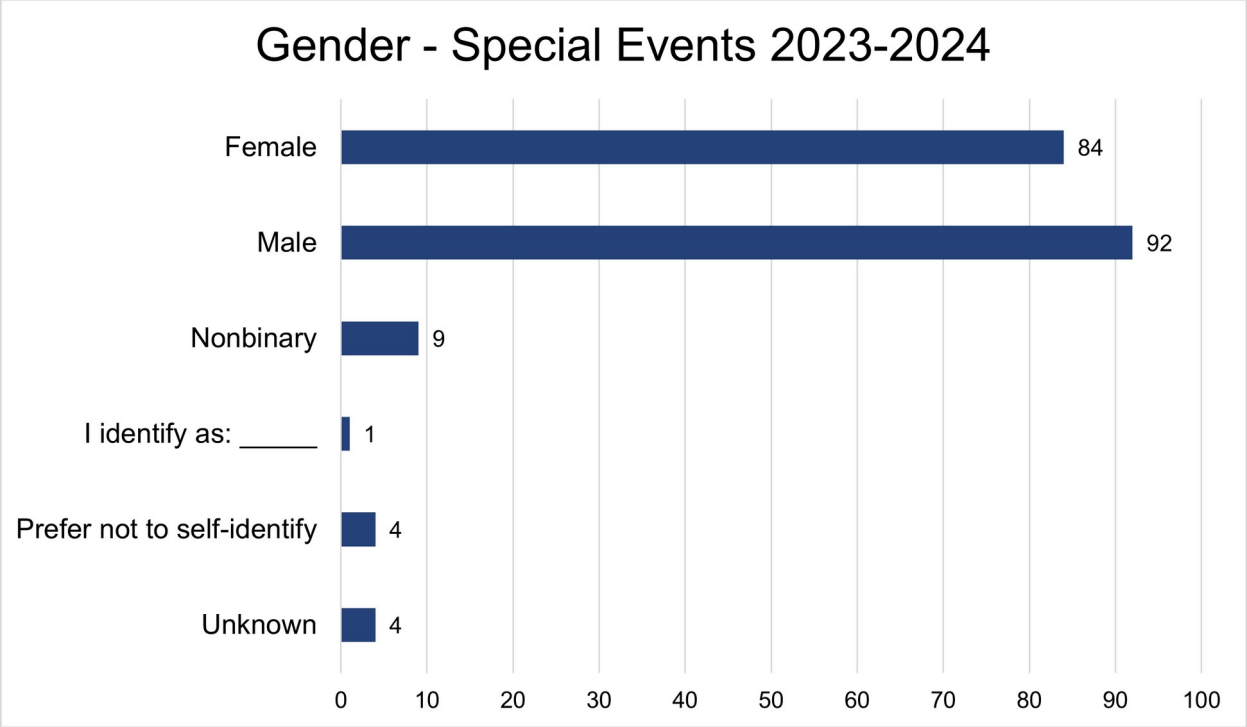
Long Programs 2023-2024 - Participants by Employer/School Location			
Country	Number of Participants	Country	Number of Participants
Canada	3	Japan	1
Denmark	1	Netherlands	1
Finland	2	South Africa	2
France	7	Spain	2
Germany	13	Sweden	5
India	1	United Kingdom	2
Italy	1	United States	48

2.5 Demographics for Special Events

The following demographic information includes participants, organizers, speakers, facilitators, and panelists.

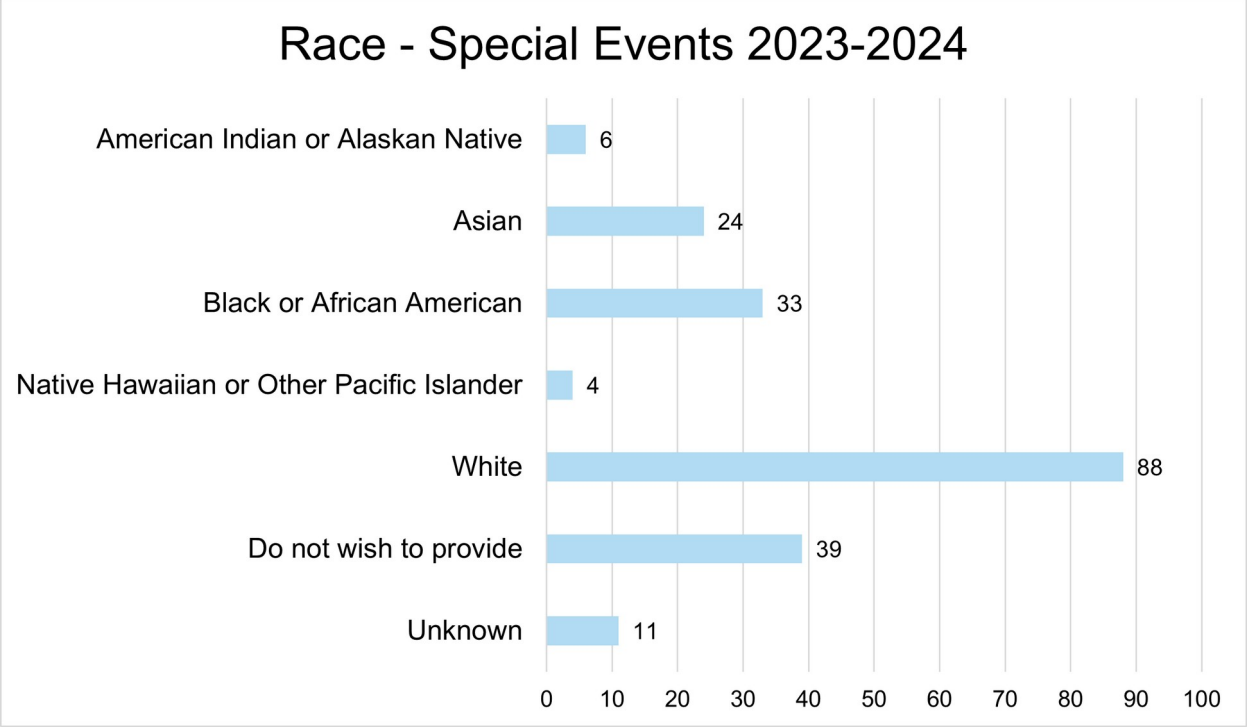
- Career Paths in the Mathematical Sciences
- BRING MATH: Bridges for the Next Generation: Mathematical Science Research and Our Future
- Modern Mathematics Workshop

Special Events 2023-2024 - Participants by Gender



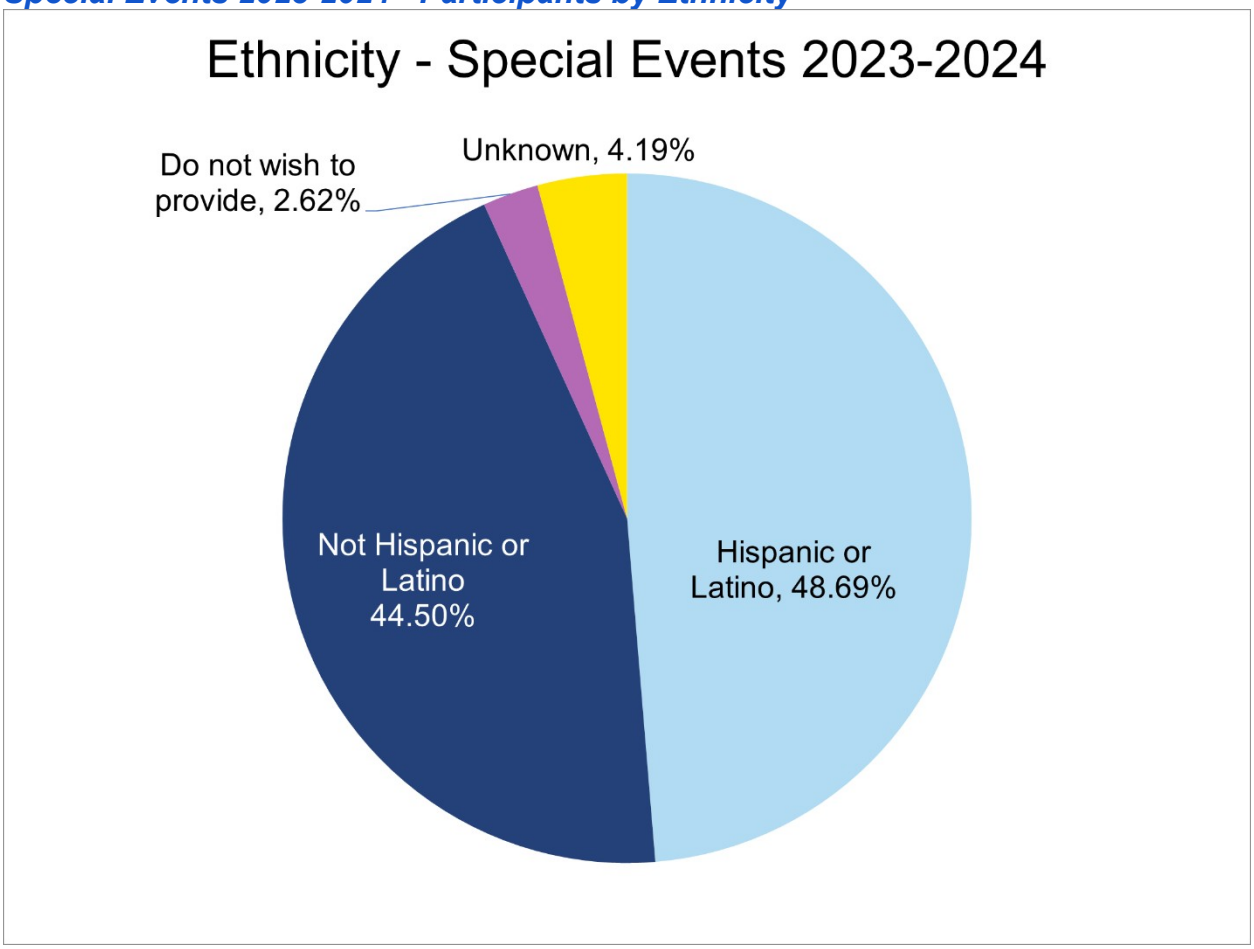
Note: Participants could select multiple genders. Some individuals may be reflected in this chart more than once.

Special Events 2023-2024 - Participants by Race

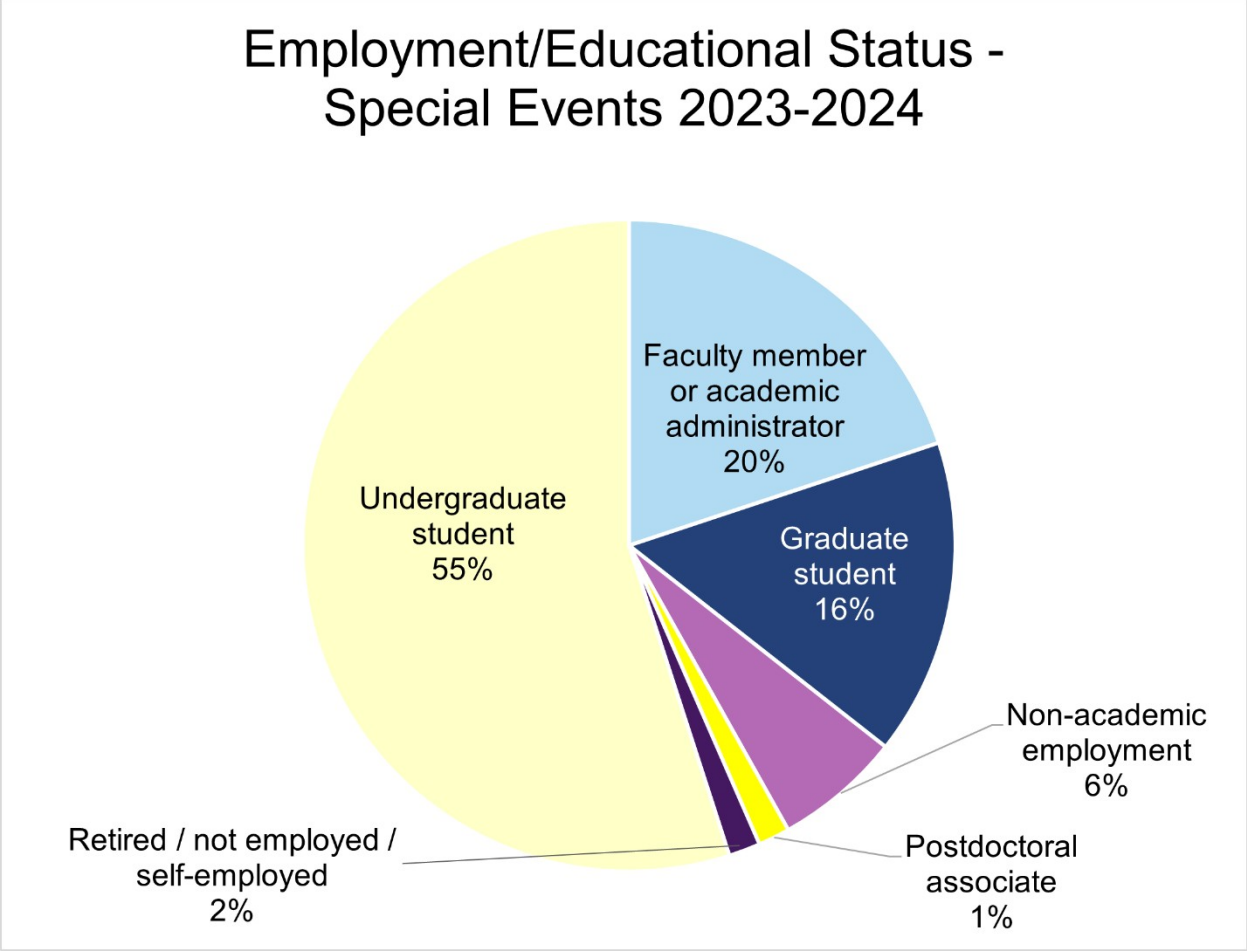


Note: Participants could select multiple races. Some individuals may be reflected in this chart more than once.

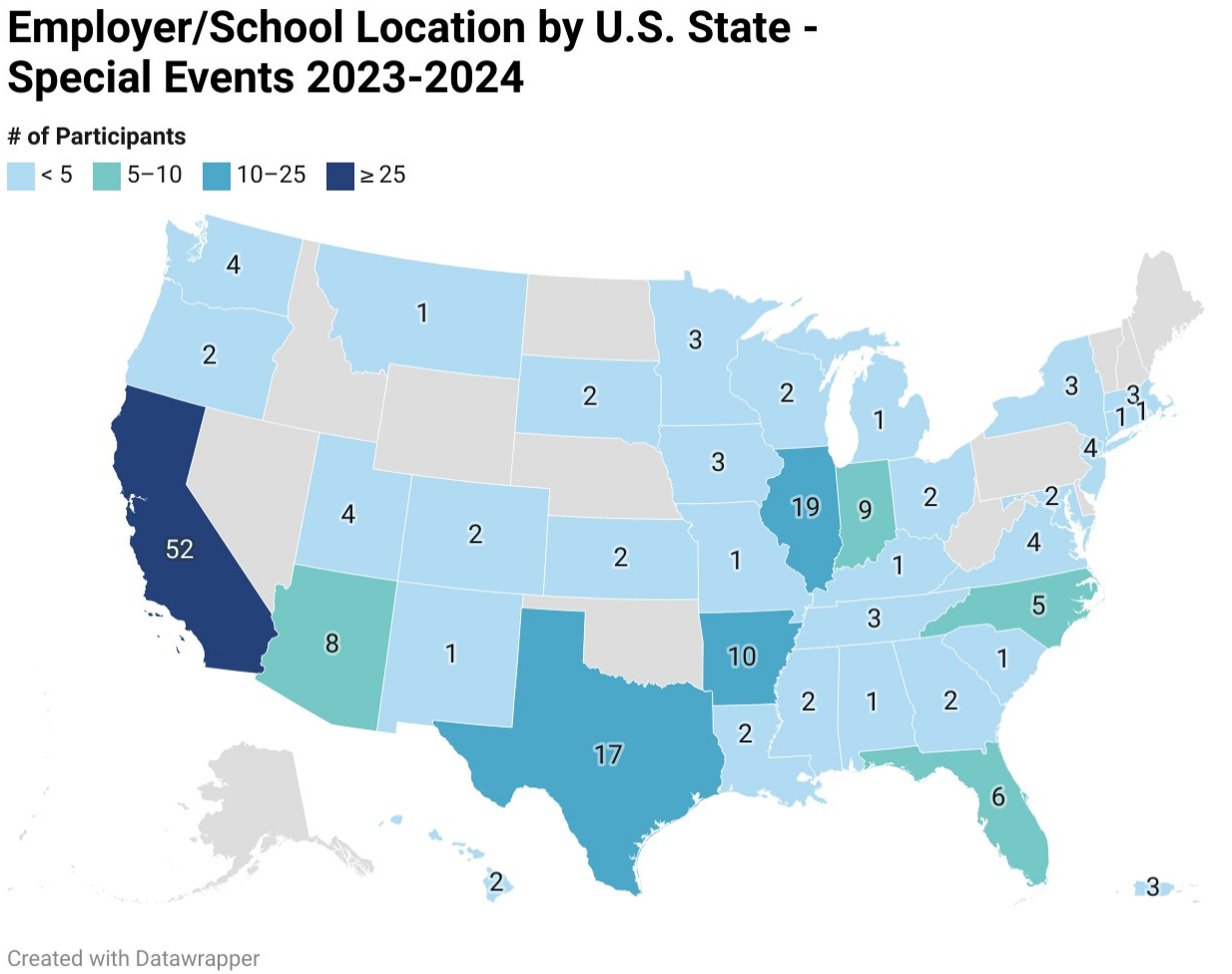
Special Events 2023-2024 - Participants by Ethnicity



Special Events 2023-2024 - Participants by Employment/Educational Status



Special Events 2023-2024 - Participants by Employer/School Location (United States)



Special Events 2023-2024 - Participants by Employer/School Location (United States)			
State	Number of Participants	State	Number of Participants
Alabama	1	Montana	1
Alaska	0	Nebraska	0
Arizona	8	Nevada	0
Arkansas	10	New Hampshire	0
California	52	New Jersey	4
Colorado	2	New Mexico	1
Connecticut	1	New York	3
Delaware	0	North Carolina	5

District of Columbia	0	North Dakota	0
Florida	6	Ohio	2
Georgia	2	Oklahoma	0
Hawaii	2	Oregon	2
Idaho	0	Pennsylvania	0
Illinois	19	Puerto Rico	3
Indiana	9	Rhode Island	1
Iowa	3	South Carolina	1
Kansas	2	South Dakota	2
Kentucky	1	Tennessee	3
Louisiana	2	Texas	17
Maine	0	Utah	4
Maryland	2	Vermont	0
Massachusetts	3	Virginia	4
Michigan	1	Washington	4
Minnesota	3	West Virginia	0
Mississippi	2	Wisconsin	2
Missouri	1	Wyoming	0

3. Description of Activities

For each activity, organizers, speakers, panelists, and other presenters are listed. Full participant lists are included in an appendix.

3.1 Fall 2023 Long Program: Algebraic Statistics and Our Changing World

IMSI hosted a long program on Algebraic Statistics and Our Changing World from September 18 through December 15, 2023. The program workshops are described in greater detail below.

This program focused on mathematical and statistical challenges arising in applications central to our changing world: 1) modeling environmental and ecological systems so that we can better understand the effects of climate change on these systems, 2) reimagining urban development and economic systems to address persistent inequity in daily living activities, and 3) providing theoretical underpinnings for modern statistical learning tech-

niques to understand the implications of widespread use and for easy adaptation to novel applications.

These are all hard challenges, but by bringing together biologists, social scientists, econo mists, statisticians, and mathematicians, and viewing the challenges collaboratively through the lens of algebraic statistics and more generally, nonlinear algebra, we can utilize this new perspective to address these challenges side-by-side.

Combinatorics, algebra, and geometry underlie many of the statistical challenges present in the three focus applications of the program. For example, modeling and inferring biolog ical and social networks relies on statistical models that are fundamentally algebraic, and in many cases, estimation is done using combinatorial walks, while understanding modern statistical learning techniques relies on understanding principles rooted in algebraic geometry. Due to such underlying mathematical structures, algebraic and geometric methods have had a long history in statistics, from which the field of algebraic statistics has grown. By taking specific problems and identifying the underlying geometry and alge bra, this program paired domain-specific expertise and recent developments in algebraic statistics to develop interdisciplinary connections aimed at addressing new applications. The goal of the program was to see where progress can be made on these applications, and also identify the mathematical and computational tools that will be needed in the future.

In addition to the embedded workshops and the Apprenticeship Week (all described in more detail below), the participants formed working and reading groups that met regularly through course of the program when workshops were not taking place. There were several such groups, organized around topics such as Causality, Maximum Likelihood Threshold for Colored Gaussian Graphical Models, Game Theory, Incomplete U-Statistics for Phylogenetic Models, and Neurovarieties of Rational Neural Networks. Additional activities included a Questions and Consulting Seminar Series, which brought in invited speakers who presented open problems to the community, daily Spotlight talks by program participants, and “Perfect Fit” seminars given by newly arrived program participants or local area experts. Further details can be found in the report of the program organizing committee, which is included in an appendix.

Organizers	Affiliation & Department
Mathias Drton	Technical University of Munich, Computation Information and Technology
Elizabeth Gross	University of Hawaii, Manoa, Mathematics
Lek-Heng Lim	University of Chicago, Statistics
Sonja Petrović	Illinois Institute of Technology, Applied Mathematics
Elina Robeva	University of British Columbia, Mathematics
Jose Rodriguez	University of Wisconsin, Madison, Mathematics

Bernd Sturmfels	Max-Planck Institute for Mathematics in the Sciences, Applied Mathematics
Piotr Zwiernik	University of Toronto, Statistical Sciences

IMSI hosted 60 participants for this long program, eight of whom were organizers.

Here are some quotes from final reports of research members:

- *I have been here at IMSI for my last semester of graduate school, and this semester has been the best experience I have had in graduate school. I have learned so much from the community here, not just from the talks, but from collaborating in working groups as well as through informal discussions with other participants.*
- *My 3-week visit (with 1 week being a workshop) was both stimulating and productive. Having the opportunity to interact directly with researchers both in and near my area of focus, for a longer time than a brief conference, enabled more thoughtful planning of future work, as well as more substantive understanding of the accomplishments of others.*
- *IMSI provided a great environment for me to make my current projects more interdisciplinary. The conferences were really helpful because there were many experts in adjacent fields visiting.*
- *I really enjoyed being able to meet people from other fields of math, statistics, economics, and computer science.*
- *Two of the research studies I have been working on for the past 1+ years were completed during my time here at IMSI.*
- *My favorite part of the program was definitely the times in between scheduled events where I was able to work with other long program participants.*
- *I appreciate the rare opportunity to collaborate with researchers from different backgrounds, from which I learned many valuable lessons. The exposure to a plethora of topics through workshops and informal talks expanded my research horizon. The continuous periods dedicated to research allowed me to delve deep into a new research project, which greatly improved my coding skills and understanding of statistics.*

The embedded workshops for the long program were as follows.

Workshop 1: Invitation to Algebraic Statistics and Applications, September 18-22, 2023

The goal of the Long Program was to identify emerging trends and interactions between nonlinear algebra, geometry, combinatorics with data science, machine learning, social sciences, economics, and ecology. To this end, this introductory workshop outlined the mathematical and computational tools that algebraic statistics offers for the fundamental problem of statistical inference and modeling. It also identified themes that the program

developed. Lectures covered algebraic statistics basics in terms of focused applications to establish a common language for participants of the program coming from varying disciplines.

The workshop was attended by 111 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Serkan Hosten	San Francisco State University, Mathematics
Thomas Kahle	Otto-von-Guericke Universität Magdeburg, Mathematics
Kaie Kubjas	Aalto University, Mathematics and Systems Analysis
Fatemeh Mohammadi	KU Leuven, Computer Science and Mathematics
Guillaume A. Pouliot	University of Chicago, Public Policy
Jose Israel Rodriguez	University of Wisconsin, Madison, Mathematics
Speakers	**Affiliation & Department**
Carlos Améndola	Technische Universität Berlin, Mathematics
Tianran Chen	Auburn University at Montgomery, Mathematics
Elizabeth Gross	University of Hawai'i at Mānoa, Mathematics
Joe Kileel	University of Texas, Austin, Mathematics
Kathlén Kohn	KTH Royal Institute of Technology, Mathematics
Julia Lindberg	University of Texas, Austin, Mathematics
Pratik Misra	KTH Royal Institute of Technology, Mathematics
Irem Portakal	Technical University of Munich (TUM), Mathematical Statistics
Seth Sullivant	North Carolina State University, Mathematics
Neriman Tokcan	University of Massachusetts Boston, Mathematics

Workshop 2: Apprenticeship Week: Varieties from Statistics, October 2-6, 2023

Algebraic statistics is concerned with statistical models that can be described by polynomials. The zero sets of these polynomials are interesting objects in algebraic geometry. This hands-on workshop was aimed at graduate students and beginning postdocs inter-

ested in this area. Participants were grouped into nine teams, with each team working on a research project. This experience was guided by three experienced mentors.

This event served as a midpoint in a process that started in August 2023 with groups meeting online to discuss their projects, coming together in person during the Apprentice ship Week to continue their work, and continuing work after the event. Each group produced a draft research paper by December 15, 2023. After a process of review and feed back, all nine papers were submitted to the journal *Algebraic Statistics*.

The workshop was attended by 31 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Serkan Hosten	San Francisco State University, Mathematics
Kaie Kubjas	Aalto University, Mathematics and Systems Analysis
Bernd Sturmfels	Max Planck Institute for Mathematics in the Sciences, Nonlinear Algebra

Workshop 3: Algebraic Statistics for Ecological and Biological Systems, October 9-13, 2023

Many models in ecology, evolutionary biology, and, more generally, biological systems, have underlying graphical structures. These include probabilistic models such as Gaussian graphical models, staged tree models, structural equation models, and latent tree models, as well as deterministic models, such as linear compartment models. Drawing on current trends and strengths in algebraic statistics, this workshop put such models front and center by introducing existing techniques and known challenges. Motivated by evolutionary biology, microbiomes, epidemiology, and ecosystem modeling, the workshop was multidisciplinary, and brought together researchers from multiple fields to study these combinatorial models and their applications.

The workshop was attended by 93 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Eliana Duarte Gelvez	Universidade do Porto, Mathematics
Elizabeth Gross	University of Hawai'i at Mānoa, Mathematics
Elina Robeva	University of British Columbia, Mathematics
Seth Sullivant	North Carolina State University, Mathematics

Speakers	Affiliation & Department
Daniel Bernstein	Tulane University, Mathematics
Andrew Brouwer	University of Michigan, Epidemiology
Jane Coons	Oxford University, Mathematics
Mathias Drton	Technical University of Munich (TUM); Computation Information and Technology
Marisa Eisenberg	University of Michigan, Center for the Study of Complex Systems
Marina Garrote-López	Max Planck Institute for Mathematics in the Sciences, Nonlinear Algebra
Gill Grindstaff	Oxford University, Mathematics
Yuqi Gu	Columbia University, Statistics
Roser Homs Pons	Centre de Recerca Matemàtica (CRM)
Thomas Kahle	Otto-von-Guericke Universität Magdeburg, Institute of Algebra and Geometry
Aida Maraj	University of Michigan, Mathematics
Alex Markham	KTH Royal Institute of Technology, Mathematics
Nikki Meshkat	Santa Clara University, Mathematics
Chris Muir	University of Wisconsin, Madison, Botany
John Rhodes	University of Alaska Fairbanks, Mathematics
Claudia Solis Lemus	University of Wisconsin, Madison, Plant Pathology
Neriman Tokcan	University of Massachusetts, Boston, Mathematics
Samuel Wang	Cornell University, Statistics
Kun Zhang	Carnegie Mellon University, Philosophy, Machine Learning
Piotr Zwiernik	University of Toronto, Statistical Sciences

Workshop 4: Algebraic Economics, November 6-10, 2023

This workshop brought together experts and young researchers from the fields of algebraic statistics and economics interested in tackling challenging problems in social sciences, public policy, and urban development. The workshop fostered collaboration and

identified emerging trends between two fields that traditionally have not interacted much. Experts presented state of the art research on topics that included data privacy, causal in ference, dynamical systems, network models, game theory, information trade, and auctions. These are topics that have been classically studied in both fields but in different frameworks. For this reason, plenty of time was devoted to creating a common language and for discussion of open problems.

The workshop was attended by 69 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Mladen Kolar	University of Chicago, Booth School of Business
Sonja Petrović	Illinois Institute of Technology, Applied Mathematics
Piotr Zwiernik	University of Toronto, Statistical Sciences
Speakers	**Affiliation & Department**
Majid Al-Sadoon	Durham University, Economics
Bryon Aragam	University of Chicago, Booth School of Business
Weslynne Ashton	Illinois Institute of Technology, Stuart School of Business
Eric Auerbach	Northwestern University, Economics
Souvik Dhara	Purdue University, Industrial Engineering
Robin Evans	University of Oxford, Statistics
Fabrizio Germano	Universitat Pompeu Fabra, Economics
Ben Golub	Northwestern University, Economics
Yuqi Gu	Columbia University, Statistics
Ben Hollering	Max Planck institute for Mathematics in the Sciences, Nonlinear Algebra
Vishesh Karwa	Temple University, Statistics
Geert Mesters	Universitat Pompeu Fabra, Economics
Debdeep Pati	Texas A&M University, College Station, Statistics
Irem Portakal	Max Planck institute for Mathematics in the Sciences, Interdisciplinary Frontiers of Algebraic Geometry
Leonard Schulman	CalTech

Aleksandra Slavkovic	Pennsylvania State University
Liam Solus	KTH Stockholm
Yuhao Wang	Tsinghua University

Workshop 5: Bayesian Statistics and Statistical Learning: New Directions in Algebraic Statistics, December 11-15, 2023

This workshop explored new directions for algebraic statistics in the realm of Bayesian statistics and statistical learning. They covered a broad range of problems from modern statistics and machine learning for which underlying algebraic structure provides a common theme. Topics of particular interest were singular models and variational inference, invariance and equivariance in statistics and machine learning, and new interdisciplinary connections between computational algebraic geometry and machine learning.

The workshop was attended by 88 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Mathias Drton	Technical University of Munich, Mathematics
Jonathan Hauenstein	University of Notre Dame, Applied and Computational Mathematics and Statistics
Lek-Heng Lim	University of Chicago, Statistics
Debdeep Pati	Texas A&M University, College Station, Statistics
Speakers	Affiliation & Department
Bryon Aragam	University of Chicago, Booth School of Business
Emma Cobian	University of Notre Dame, Applied Mathematics
Jesús de Loera	University of California, Davis, Mathematics
Nadav Dym	Technion – Israel Institute of Technology, Mathematics
Kathryn Heal	Google
Peter Hoff	Duke University, Statistical Science
Vishesh Karwa	Temple University, Statistics
Joe Kileel	University of Texas, Austin, Mathematics and Oden Institute

Kathlén Kohn	KTH Royal Institute of Technology, Mathematics
Risi Kondor	University of Chicago, Computer Science and Statistics
Shaowei Lin	Topos Institute
Andrew McCormack	Duke University, Statistics
Guido Montufar	University of California, Los Angeles, Mathematics and Statistics & Data Science
XuanLong Nguyen	University of Michigan, Statistics
Luke Oeding	Auburn University, Mathematics and Statistics
Sean Plummer	University of Arkansas, Fayetteville, Mathematics
Judith Rousseau	University of Oxford, Statistics
Kazuho Watanabe	Toyohashi University of Technology, Computer Science and Engineering
Sumio Watanabe	Tokyo Institute of Technology, Applied Mathematics
Han Xiao	Rutgers University, Statistics

3.2 Spring 2024 Long Program: Data-Driven Materials Informatics

IMSI hosted a long program on Data-Driven Materials Informatics from March 4 through May 24, 2024. The program workshops are described in greater detail below.

Materials informatics is an emerging field defined by the use of simulation tools combined with methods from data sciences and machine learning to better understand materials properties and design innovative materials. The models which are considered cover an extremely wide range, from Schrödinger's equation, which describes matter at the (sub)atomic scale, to the equations of continuum mechanics. Mathematical sciences play a key role in materials informatics, to construct the databases used to train machine learn ing algorithms (since these databases are made of reference simulation results), and to harness them in order to extract the most relevant information. The aim of this program was to bring together a diverse scientific audience, between scientific fields (physical sciences, materials sciences, biophysics, etc) and within mathematics (mathematical model ing, numerical analysis, statistics and data analysis, etc), to make progress on key questions of materials informatics.

Outside of workshop weeks, the program included a seminar series in which every long-term participant was given the opportunity to present their research, working groups, tuto rials during the week prior to some of the embedded workshops, and training sessions by IMSI Director of Communications and Engagement. The working groups focused on top ics such as force fields, data-driven scale bridging, approximation of the committor function, and generative methods for rare event sampling. More details can be found in the re port of the program organizing committee, which is included in an appendix.

Organizers	Affiliation & Department
Claudia Draxl	Humboldt-Universität zu Berlin, Physics
Risi Kondor	University of Chicago, Computer Science, Statistics
Marina Meila	University of Washington, Statistics
Danny Perez	Los Alamos National Laboratory
Gabriel Stoltz	École des Ponts ParisTech, Mathematical and Computer Engineering
François Willaime	Commissariat à L'Energie Atomique et aux energies alternatives (CEA)

IMSI hosted 33 participants for this long program, six of whom were organizers.

Here are some quotes from final reports of research members:

- *I really enjoyed the program, the workshops brought together experts from all over the world and in the off-workshop weeks the opportunities to work on ideas*

which resulted from the discussions during the workshop. Overall an amazing experience.

- *The workshops were particularly lively! I appreciated the possibility to have some training on outreach activities.*
- *The selection of speakers and topics were top notch. Even the scheduling of the speakers in the workshops was remarkably coherent and conducive to better communication.*
- *The staff are wonderful and friendly. They are always very helpful when needed. The office space and the overall IMSI office environments is exceptionally stimulating and comfortable for academic research and social interactions.*
- *The collaboration formed during the off-workshop weeks and great support from the staff at IMSI.*

The embedded workshops for the long program were as follows.

Workshop 1: Materials Informatics: Tutorials and Hands-on, March 11-15, 2024

The aim of this one-week tutorial session was to lay the scientific foundations for the vari ous workshops and events of the Long Program. It concentrated on two aspects: 1) data sciences and machine learning methods in a broad sense, starting from basic methods such as principal component analysis and clustering methods, to more advanced topics related to kernel methods, neural networks, generative techniques and reinforcement learning to name a few, and 2) the construction and usage of databases of interest for ma terials science. The tutorial session included lectures and hands-on sessions.

The workshop was attended by 71 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Claudia Draxl	Humboldt-Universität zu Berlin, Physics
Risi Kondor	University of Chicago, Computer Science, Statistics
Gabriel Stoltz	École des Ponts ParisTech, Mathematical and Computer Engineering
Chris Wolverton	Northwestern University, Materials Science and Engineering
Speakers	Affiliation & Department
Yuxin Chen	University of Chicago, Computer Science
Kamal Choudhary	National Institute of Standards and Technology
Stefano Curtarolo	Duke University, Mechanical Engineering and Materials Science
Luca Ghiringhelli	Friedrich-Alexander-Universität Erlangen-Nuremberg, Materials Sci-

	ence and Engineering
Yuehaw Khoo	University of Chicago, Statistics
Vitaliy Kurlin	University of Liverpool, Computer Science
Cong Ma	University of Chicago, Statistics
Michael Maire	University of Chicago, Computer Science
Grant Rotskoff	Stanford University, Chemistry
K.J Schmidt	University of Chicago, Globus
Eugene Vinitsky	New York University, Civil and Urban Engineering
Logan Ward	Argonne National Laboratory

Workshop 2: Machine Learning in Electronic-Structure Theory, March 25-29, 2024

Machine learning (ML) approaches are transforming the field of electronic structure calcu lations. This is particularly true for Density Functional Theory (DFT), the most widely used quantum mechanical approach in computational materials science. ML allows researchers to recast the search for the ground state of the Schrödinger operator into the minimization of a functional of the electronic density of the system, a function in three vari ables only. The caveat is that the form of the functional is unknown. The very efficient Kohn-Sham (KS) scheme proposed in the 60's, in which only the exchange-correlation (XC) energy needs to be approximated, still faces some limitations, despite intense efforts in the physics and chemistry communities. Machine learning (ML) is promising for improv ing density-functional approximations, either to find the best combination of current XC approximations, or to construct new XC functionals or even to produce pure density func tionals to bypass the need to solve KS equations. Besides tackling the total energy in that way, ML can also be used to predict the electronic structure from higher-level methodology like Green-function approaches. Moreover, ML is also very promising for other complementary electronic structure methods, e.g. to solve the bottleneck of the parametrization of tight-binding Hamiltonians on DFT calculations or to improve the efficiency of the highly-accurate Quantum Monte Carlo methods that have prohibitive computational cost for large systems.

The workshop was attended by 117 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Claudia Draxl	Humboldt-Universität zu Berlin, Physics

Giulia Galli	University of Chicago, Pritzker School of Molecular Engineering
Lin Lin	University of California, Berkeley, Mathematics
François Willaime	Commissariat à L'Energie Atomique et aux energies alternatives (CEA)
Speakers	Affiliation & Department
Nilin Abrahamsen	University of California, Berkeley, Mathematics
Fabien Bruneval	Commissariat à L'Energie Atomique et aux energies alternatives (CEA), and Université Paris-Saclay
Kieron Burke	University of California, Irvine, Chemistry
Attila Cangi	Helmholtz-Zentrum Dresden-Rossendorf
Roberto Car	Princeton University, Chemistry
Giuseppe Carleo	EPFL (Ecole Polytechnique Fédérale de Lausanne), Institute of Physics
Maria Chan	Argonne National Laboratory
Marivi Fernández-Serra	Stony Brook University, Physics and Astronomy
Laura Gagliardi	University of Chicago, Chemistry
Luca Ghiringhelli	Friedrich-Alexander-Universität Erlangen-Nuremberg, Materials Science and Engineering
Yuehaw Khoo	University of Chicago, Statistics
Boris Kozinsky	Harvard University, Engineering and Applied Sciences
Heather Kulik	Massachusetts Institute of Technology, Chemical Engineering and Chemistry
Michael Lindsey	University of California, Berkeley, Mathematics
Jianfeng Lu	Duke University, Mathematics
David Mazziotti	University of Chicago, Chemistry
Frank Noé	Freie Universität Berlin, Mathematics and Computer Science
Lucia Reining	Centre National de la Recherche Scientifique (CNRS)
Santiago Rigamonti	Humboldt-Universität zu Berlin, Physics
Tess Smidt	Massachusetts Institute of Technology, Electrical Engineering and Computer Science

Berend Smit	EPFL (Ecole Polytechnique Fédérale de Lausanne), Chemistry
Alexandre Tkatchenko	University of Luxembourg, Physics and Materials Science
Jonathan Weare	New York University, Mathematics

Workshop 3: Machine Learning Force Fields, April 8-12, 2024

Atomistic simulations such as molecular dynamics (MD) are a cornerstone of computational material science. MD is a powerful tool that can generate fully-resolved (classically), dynamically correct trajectories based only on a description of the energetics of the interactions between atoms. A longstanding challenge in MD is the development of approximations to the exact quantum potential energy surface that are computationally affordable and scalable, therefore enabling simulations of much larger systems over much longer times than are possible using direct solutions to Schrödinger's equation.

Until recently, the functional form of these so-called interatomic potentials was largely based on physical considerations. In past years, machine learning approaches thoroughly reshaped the field through the introduction of numerical methods which require less prior knowledge, lead to lower regression errors, and better transferability. While machine learning has shown great promise, developments are often still guided by *ad hoc* heuristics, which slows down further progress. This calls for a rigorous study of the modeling and numerical errors involved in the representation of forces and energies obtained from quantum mechanics by models of classical mechanics, through *a priori* or *a posteriori* error estimates, of uncertainty quantification for detecting which parameters influence most the results, of the influence of the training database, or how it should be augmented to minimize prediction errors.

This workshop explored mathematical challenges of this kind and discussed how fundamental insights can be translated into practical improvements in the cost/accuracy tradeoff of the next generation of data-driven interatomic potentials, enabling robust large-scale simulations at unprecedented accuracies and spatio-temporal scales.

The workshop was attended by 88 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Geneviève Dusson	Centre National de la Recherche Scientifique (CNRS)
Risi Kondor	University of Chicago, Computer Science and Statistics
Christoph Ortner	University of British Columbia, Mathematics

Danny Perez	Los Alamos National Laboratory
Speakers	Affiliation & Department
Alice Allen	Los Alamos National Laboratory
Ilyes Batatia	University of Cambridge, Engineering
Anton Bochkarev	Ruhr-Universität Bochum, Interdisciplinary Centre for Advanced Materials Simulation (ICAMS)
Michele Ceriotti	EPFL (Ecole Polytechnique Fédérale de Lausanne)
Rose Cersonsky	University of Wisconsin, Madison, Chemical and Biological Engineering
Bingqing Cheng	University of California, Berkeley, and Institute of Science and Technology Austria (IST Austria), Chemistry
Gábor Csanyi	University of Cambridge, Engineering
Ralf Drautz	Ruhr-Universität Bochum, Interdisciplinary Centre for Advanced Materials Simulation (ICAMS)
Elena Gelzinyte	Fritz-Haber-Institut der Max-Planck-Gesellschaft
James Goff	Sandia National Laboratory, Center for Computing Research
Teresa Head-Gordon	University of California, Berkeley, Chemistry
Jan Janssen	Max-Planck-Institut für Eisenforschung GmbH, Computational Materials Design
James Kermode	University of Warwick, School of Engineering
Julien Lam	Centre National de la Recherche Scientifique (CNRS)
Cosmin Marinica	Commissariat à L'Energie Atomique et aux energies alternatives (CEA), and Université Paris-Saclay
Ngoc-Cuong Nguyen	Massachusetts Institute of Technology, Aeronautics and Astronautics
Jigyasa Nigam	EPFL (Ecole Polytechnique Fédérale de Lausanne), Physics
Cameron Owen	Harvard University, Chemistry and Chemical Biology
Cas van der Oord	University of Cambridge, Engineering
Danny Perez	Los Alamos National Laboratory
Yangshuai Wang	University of British Columbia, Mathematics
Roman Zubatyuk	Carnegie Mellon University, Chemistry

Lightning Talk Speakers	Affiliation & Department
William Baldwin	University of Cambridge, Engineering
Fraser Birks	University of Warwick, Heterogeneous Systems CDT
Luella Fu	San Francisco State University, Mathematics
Cheuk Hin Ho	University of British Columbia, Mathematics
Chunghee Nam	Hannam University, Electrical and Electronic Engineering
Thomas Pigeon	IFP Energies nouvelles
Perrin Ruth	University of Maryland College Park, Mathematics
Lars Schaaf	University of Cambridge, Engineering
Thomas Swinburne	Centre National de la Recherche Scientifique (CNRS)

Workshop 4: Learning Collective Variables and Coarse Grained Models, April 22-26, 2024

The dynamical behavior of molecular systems of relevance to chemistry, biophysics and materials science can be numerically simulated using deterministic molecular dynamics algorithms or stochastic algorithms such as Langevin dynamics. Although the systems of interest are composed of large numbers of atoms, collective interactions mean that the long-time evolution is typically dictated by the variations of a small number of collective modes, known as collective variables or reaction coordinates. Intense efforts have recently been invested in automating the definition of collective variables from molecular simulation data using a variety of machine learning techniques. A key mathematical question is to characterize the quality of the dimensionality reduction, for instance by *a priori* or, even better, *a posteriori* estimates on the error committed by integrating the dynamics associated with the coarse-grained reduced model. Another important issue is how to incorporate various constraints into the discovery process, such as symmetries (permutation, rotation, translation). This workshop focused on recent advances in the data driven learning and validation of collective modes and their applications in coarse-grained simulations and enhanced sampling.

The workshop was attended by 119 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Andrew Ferguson	University of Chicago, Pritzker School of Molecular Engineering

Bettina Keller	Freie Universität Berlin, Department of Biology, Chemistry, Pharmacy
Marina Meila	University of Washington, Statistics
Jutta Rogal	New York University and Freie Universität Berlin, Physics and Chemistry
Gabriel Stoltz	École des Ponts ParisTech, Mathematical and Computer Engineering
Speakers	Affiliation & Department
David Aristoff	Colorado State University, Fort Collins, Mathematics
Marloes Arts	Genmab
Peter Bolhuis	University of Amsterdam, Van 't Hoff Institute for Molecular Sciences
Klara Bonneau	Freie Universität Berlin, Physics
Christophe Chipot	Centre National de la Recherche Scientifique (CNRS)
Pilar Cossio	Flatiron Institute
Roberto Covino	Frankfurt Institute for Advanced Studies
Bernd Ensing	University of Amsterdam, Van 't Hoff Institute for Molecular Sciences
Andrew Ferguson	University of Chicago, Pritzker School of Molecular Engineering
Laura Filion	University of Utrecht, Physics
Paraskevi Gkeka	Sanofi R&D
Rafael Gomez-Bombarelli	Massachusetts Institute of Technology (MIT), Materials Science and Engineering
Nick Jackson	University of Illinois at Urbana-Champaign, Chemistry
Tony Lelièvre	École des Ponts ParisTech, Mathematical and Computer Engineering
Marina Meila	University of Washington, Statistics
Karen Palacio-Rodriguez	Max Planck Institute of Biophysics, Theoretical Biophysics
Grant Rotskoff	Stanford University, Chemistry
Yusu Wang	University of California, San Diego (UCSD), Halıcıoğlu Data Science Institute
Rose Yu	University of California, San Diego (UCSD), Computer Science and Engineering

Hanyu Zhang	TikTok
Ming Zhong	Illinois Institute of Technology, Applied Mathematics
Poster Presenters	Affiliation & Department
Eric Beyerle	University of Maryland, College Park, Institute for Physical Science and Technology
Matteo Carli	Harvard University, School of Engineering and Applied Science
Yaoyi Chen	Freie Universität Berlin and Zuse Institute Berlin, Artificial Intelligence for the Sciences
Xiaoou Cheng	New York University, Mathematics
Luke Evans	Flatiron Institute, Center for Computational Biology and Center for Computational Mathematics
Abhik Ghosh Moulick	CUNY - College of Staten Island, Chemistry
Andrea Guljas	Free University of Berlin and Zuse Institute Berlin, Physics
Spencer Guo	University of Chicago, Chemistry
Carl Henning Hansen	University of Copenhagen, Biology
Mike Jones	University of Chicago, Pritzker School of Molecular Engineering
Suemin Lee	University of Maryland, Biophysics
Chatipat Lorpaiboon	University of Chicago, Chemistry
John Maier	University of Illinois at Urbana-Champaign, Physics
Juno Nam	Massachusetts Institute of Technology (MIT), Materials Science and Engineering
Rutika Patel	City University of New York (CUNY), Chemistry
Thomas Pigeon	IFP Energies nouvelles
Adolfo Poma	Institute of Fundamental Technological Research Polish Academy of Sciences, Biosystems and Soft Matter
Deepika Sardana	EPFL (Ecole Polytechnique Federale de Lausanne), Chemistry
Subarna Sasmal	New York University, Chemistry
Shashank Sule	University of Maryland, Mathematics
Dallas Trinkle	University of Illinois at Urbana-Champaign, Materials Science and Engineering

Soojung Yang	Massachusetts Institute of Technology (MIT), Computational and Systems Biology

Workshop 5: Data Sciences for Mesoscale and Macroscale Materials Models, May 13-17, 2024

Contemporary computational materials science relies on an ecosystem of models that span an extremely broad range of characteristic time and length scales. These range from quantum mechanics-based methods at the smallest length and timescales to macroscale finite element approaches at the largest length scales. This includes for instance models to predict the evolution of defects in materials, such the kinetic Monte Carlo method or cluster dynamics; or models of plasticity that employ either dislocation dynamics at the mesoscopic scale or crystal plasticity, at the macroscopic scale. The evolution of defects and microstructures can in parallel be studied with experimental characterizations and imaging devices, e.g., techniques dedicated to monitoring the evolution of microstructures (such as grain coarsening with X-ray tomography).

A longstanding challenge in the field is to develop systematic techniques to leverage all available data sources to develop accurate materials models. However, due to the wide range of different computational model formulations and scales (phase field, discrete defect models, reaction-diffusion equations), of numerical approaches (spectral methods, fi nite elements, particle solvers), and of experimental data streams, mathematical challenges related to the design and efficient execution of data-driven meso- and macro-scale models abound.

This workshop will focus on the challenge of informing meso and macro-scale models from data, either obtained from lower-scale computations or directly from experiments. Topics of interest include the use of data-driven methods to learn effective models from measured data (e.g., using sparse system identification methods, or backpropagation through PDE solvers), the development of rigorous data-driven scale-bridging techniques, or the development of optimal design of experiments methods to identify small sets of experiments or calculations that would best constrain the models at the lowest cost. We also welcome contributions related to high-throughput data generation approaches applicable to meso and macro-scale materials modeling and uncertainty quantification methods for data-driven models.

The workshop was attended by 51 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Xingjie Li	University of North Carolina at Charlotte, Mathematics and Statistics
Marina Meila	University of Washington, Statistics

Danny Perez	Los Alamos National Laboratory
Peter Voorhees	Northwestern University, Materials Science and Engineering
Speakers	Affiliation & Department
Raymundo Arroyave	Texas A&M University, College Station, Materials Science & Engineering
Soumendu Bagchi	Oak Ridge National Laboratory
Nicolas Bertin	Lawrence Livermore National Laboratory
Weiqi Chu	University of Massachusetts, Amherst, Mathematics and Statistics
Yixiang Deng	Ragon Institute of Mass General, MIT, and Harvard
Krishna Garikipati	University of Southern California (USC), Aerospace and Mechanical Engineering
Jason Hattrick-Simpers	University of Toronto, Materials Science & Engineering
Amanda Howard	Pacific Northwest National Laboratory (PNNL)
Thomas Hudson	University of Warwick, Mathematics Institute
Abigail Hunter	Los Alamos National Laboratory
Sergei Kalinin	University of Tennessee, Knoxville, Materials Science and Engineering
Quanjun Lang	Duke University, Mathematics
Fei Lu	Johns Hopkins University, Mathematics
Feliks Nüske	Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg
Vivek Oommen	Brown University, Engineering
Thomas Swinburne	Centre National de la Recherche Scientifique (CNRS)
Anjana Talapatra	Los Alamos National Laboratory
Molei Tao	Georgia Institute of Technology, Mathematics
Xiaochuan Tian	University of California, San Diego (UCSD), Mathematics
Dallas Trinkle	University of Illinois at Urbana-Champaign, Materials Science and Engineering
Sichen Yang	Johns Hopkins University, Applied Mathematics and Statistics

Yue Yu	Lehigh University, Mathematics

3.3 Topical Workshops

IMSI held eight research workshops during the reporting period which were outside the framework of long programs. These are described in this section.

Laplacian Growth Models: Theory and Applications, June 26-30, 2023

IMSI hosted the workshop Laplacian Growth Models: Theory and Application, June 26-30, 2023. Laplacian growth models describe the evolution of a surface separating two domains, filled with different materials or different phases of the same material. The evolution of the interface is governed by the energy imbalance along the interface, whereas the evolution of the energy is governed by a heat-like equation. There exist many versions of such models, including the Stefan and Hele-Shaw problems, and they serve as building blocks in various models of fundamental physical and biological processes: e.g., melting and solidification, condensation, crystal growth, aging of alloys, interaction of fluids with different viscosities, dynamics of membrane potentials in a network of neurons, tumor growth, etc. In addition to the applications in natural sciences, certain Laplacian growth models are also used in mathematical finance for systemic risk modeling. Due to the (typical) singularities in the solutions, to date, there exists no general well-posedness theory for Laplacian growth models. This question has received a lot of attention in the recent years, with novel probabilistic methods being combined with the more classical analytical ones to yield new existence and uniqueness results.

This workshop brought together researchers who are primarily interested in the theoretical advancement of Laplacian growth models, and those who approach this topic from an applied point of view. This combination generated synergies: on the one hand, many challenging questions arising in physics, biology and finance can be addressed by Laplacian growth models; on the other hand, in order to use these models one needs appropriate theoretical foundation, in particular, the well-posedness of solutions and convergence of numerical schemes. The workshop also created a bridge between the researchers who use mainly PDE and geometric analysis methods and those who primarily employ probabilistic techniques.

This workshop had 44 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Christa Cuchiero	University of Vienna, Statistics and Operations Research
Sergey Nadtochiy	Illinois Institute of Technology, Applied Mathematics
Mykhaylo Shkolnikov	Princeton University, Operations Research & Financial Engineering (ORFE)

Speakers	Affiliation & Department
Rami Atar	Technion – Israel Institute of Technology, Electrical and Computer Engineering
Irene Fonseca	Carnegie Mellon University, Mathematical Sciences
Harald Garcke	Universität Regensburg, Mathematics
Yucheng Guo	Princeton University, Operations Research & Financial Engineering (ORFE)
Mahir Hadzic	University College London, Mathematics
Mihaela Ignatova	Temple University, Mathematics
Inwon Kim	University of California, Los Angeles (UCLA), Mathematics
Lionel Levine	Cornell University, Mathematics
Scander Mustapha	Princeton University, Applied Mathematics
Eviatar Procaccia	Technion – Israel Institute of Technology, Data and Decision Sciences
Christoph Reisinger	University of Oxford, Mathematical Institute
Riccarda Rossi	University of Brescia, Mechanical and Industrial Engineering
Allan Sly	Princeton University, Mathematics
Andreas Søjmark	London School of Economics, Statistics
Mete Soner	Princeton University, Operations Research & Financial Engineering (ORFE)
Sara Svaluto-Ferro	Università degli studi di Verona, Economic Sciences
Etienne Tanré	Institut National de Recherche en Informatique et Automatique (INRIA), Mathematics
Amanda Turner	University of Leeds, Statistics
Kevin Yang	Harvard University, Mathematics

Participant comments on the workshop included the following:

- *The quality of talks and discussions was very high. I was also impressed with how the topics of the talks covered an extremely broad range of applications and, yet, were closely connected mathematically in a surprising way!*
- *The quality of the presentations and the presenters. The panel of topics, very specific and exactly my center of interest.*
- *Coffee/lunch break during which I could have conversation with other scholars.*

- *Beautiful mathematical work and a very active research topic.*
- *The variety of areas, fields and subfields that are encompassed under the title of Laplacian Growth Models.*

Object Oriented Data Analysis in Health Sciences, July 10-14, 2022

IMSI hosted the workshop, Object Oriented Data Analysis in Health Sciences, July 10-14, 2023. This workshop was for researchers in statistics and data science who invent methods for tackling complex data. The foundation is Object Oriented Data Analysis, which is a framework for approaching complex data in a principled and interdisciplinary way that is focused on actual analysis. A key concept is “data objects,” a generalization of the classi cal vectors as experimental units. This is based on the fundamental observation that collaborative discussion of the question, “what should be the data objects?” provided a fundamental approach to getting a handle on a complex interdisciplinary data analysis challenge. Motivating data challenges came from the health sciences, and methodologies that span many mathematical areas including analysis, probability, geometry and topology.

This workshop had 44 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Ian L. Dryden	Florida International University, Mathematics and Statistics
Sebastian Kurtek	Ohio State University, Statistics
J. S. Marron	University of North Carolina, Chapel Hill; Statistics
R. Todd Ogden	Columbia University, Biostatistics
Daniel Osborne	Florida A&M University, Mathematics
Megan Owen	CUNY - Herbert H. Lehman College, Mathematics
Sean L. Simpson	Wake Forest University School of Medicine, Biostatistics and Data Science

Participant comments on the workshop included the following:

- *The discussion groups were very interesting, and being able to choose different discussion groups led to a lot of variety.*
- *The discussion sessions were an amazing opportunity to exchange ideas and foster collaborations. These were instrumental in bringing together ideas from geometric statistics, applied mathematics, computer vision, and neuroscience to analyze complex data. The overall structure of this workshop (research talks followed by lengthy discussion sessions) should, in my opinion, be strongly encouraged in the future.*

- *Object Oriented Data Analysis is a promising field with challenging problems that cannot be tackled with the tools of any single subfield of statistics. It is therefore essential to encourage collaborations in order to approach these challenges from diverse angles.*
- *That there is a lot of very exciting research in Object Oriented Data Analysis, and exposure to the topics has certainly enhanced my research program. I feel that the workshop provided an excellent reinvigoration of my research, thanks to great collaborations and contacts that I made.*
- *New connections, new ideas and new scientific collaborations.*
- *Overall, seeing complex mathematical notions, such as measure spaces make their way into applied statistical analysis of graph data, shows the importance of cross-disciplinary collaboration and the continuous interplay between abstract theory and practical application in the field of object-oriented data analysis.*
- *The structure of this workshop was experimental but a big success. I enjoyed it immensely and I think it accomplished the purpose of creating new collaborative work and increasing the knowledge of the participants.*

AI+Science Summer School, July 17-21, 2023

The AI + Science Summer School was jointly sponsored by IMSI and the Data Science Institute (DSI) at the University of Chicago. It was hosted in IMSI space and applications were managed through IMSI's website. It focused on four core themes at the heart of this emerging paradigm of scientific discovery: 1) AI uncovering new laws of nature, 2) AI guiding scientific measurement, 3) physics-informed machine learning, and 4) scientific discovery advancing AI frontiers.

Organizers	Affiliation & Department
Simona Ahmed	University of Chicago, Data Science Institute
Yuxin Chen	University of Chicago, Computer Science
Aaron Dinner	University of Chicago, Chemistry
Ian Foster	University of Chicago, Computer Science, and Argonne, MCS
Peter Lu	University of Chicago, Data Science Institute
Eric Jonas	University of Chicago, Computer Science
Yuehaw Khoo	University of Chicago, Statistics
Risi Kondor	University of Chicago, Computer Science and Statistics
David W. Miller	University of Chicago, Physics, and Enrico Fermi Institute
Brian Nord	University of Chicago, Astronomy & Astrophysics and KICP, and Fermilab

Niksa Praljak	University of Chicago, Biophysics
Jordan Shivers	University of Chicago, Data Science Institute
Suri Vaikuntanathan	University of Chicago, Chemistry
Yihang Wang	University of Chicago, Chicago Center for Theoretical Chemistry
Rebecca Willett	University of Chicago, Computer Science and Statistics
Speakers	Affiliation & Department
Chibueze Amanchukwu	University of Chicago, Pritzker School of Molecular Engineering
Aishik Ghosh	Lawrence Berkeley National Laboratory
Anoushka Joglekar	New York Genome Center
Kohitij Kar	York University, Biology
Simon Kornblith	Google Brain
Katie Malone	Tempus
Krithika Manohar	University of Washington, Mechanical Engineering
Dane Morgan	University of Wisconsin, Engineering
Grant Rotskoff	Stanford University, Chemistry
Haruko Wainwright	Lawrence Berkeley National Laboratory and Massachusetts Institute of Technology (MIT), Nuclear Science and Engineering

Permutation and Causal Inference: Connections and Applications, August 22 – 25, 2023

IMSI hosted the workshop, Permutation and Causal Inference: Connections and Applications, August 22-25, 2023. Random permutation, as a particularly interesting type of stochasticity, has been a fundamental object of interest in two branches of statistics: causal inference, which focuses on drawing causal conclusions from randomized and quasi-randomized experiments; and distribution-free methods, which focuses on constructing and studying the stochastic structures of certain functionals of a distribution-free nature. The two fields have each witnessed explosive development in recent years. Notably, as the ideas of randomization, re-randomization, and multiple permutation tests have been booming in causal inference in the last ten years, conformal prediction, knock offs, rank statistics, graph-based statistics, optimal transport, combinatorial inference,

and Stein's methods have simultaneously received increasing attention in the world of distribution-free methods.

Researchers working in these two areas are now, more than ever, realizing the foundational connection between them: they are faced with similar data analysis challenges and need similar technical tools. This workshop brought together experts from these two distinct worlds, to communicate, to learn from each other, and to stimulate conversations and collaborations.

This workshop had 81 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Rina Barber	University of Chicago, Statistics
Peng Ding	University of California, Berkeley (UC Berkeley), Statistics
Fang Han	University of Washington, Statistics
Nicole Pashley	Rutgers University, Statistics
Speakers	Affiliation & Department
Mona Azadkia	ETH Zürich and London School of Economics, Statistics
Eun Yi Chung	University of Illinois at Urbana-Champaign, Economics
Tirthankar Dasgupta	Rutgers University, Statistics
Holger Dette	Ruhr-Universität Bochum, Mathematics
Colin Fogarty	University of Michigan, Statistics
Nianqiao Ju	Purdue University, Statistics
Lihua Lei	Stanford University, Stanford Graduate School of Business
Xinran Li	University of Illinois at Urbana-Champaign, Statistics
Lester Mackey	Microsoft Research New England
Sam Pimentel	University of California, Berkeley (UC Berkeley), Statistics
Adrian Roellin	National University of Singapore, Statistics and Data Science
Yaniv Romano	Technion – Israel Institute of Technology, Computer Science
Bodhisattva Sen	Columbia University, Statistics
Lei Shi	University of California, Berkeley (UC Berkeley), Biostatistics

Philip B. Stark	University of California, Berkeley (US Berkeley), Statistics
Panos Toulis	University of Chicago, Statistics
Jingshen Wang	University of California, Berkeley (UC Berkeley), Biostatistics
Jingshu Wang	University of Chicago, Statistics
Anqi Zhao	National University of Singapore, Statistics

Participant comments on the workshop included the following:

- *One of my favorite moments from the IMSI workshop on random permutations in causal inference and distribution-free methods was the opportunity to engage in rich conversations with both presenters and participants. These discussions allowed for a deeper understanding and exploration of topics like the functional-on-functional method, synthetic control method, and the Fisher randomization test. Interacting with leading experts and fellow attendees brought a depth and nuance to the subject matter that simply cannot be gained from presentations alone. The exchange of ideas, the challenging questions, and the collaborative atmosphere were truly the highlights for me.*
- *My biggest takeaway is actually a sense of how tight the community is, as well as an idea of how valuable the type of collaboration that conferences foster.*
- *As someone relatively new to the world of statistics, I've found every IMSI workshop to be incredibly enlightening.*

Teaching and Evaluating Data Communication at Scale, January 10-12, 2024

IMSI hosted the workshop, Teaching and Evaluating Data Communication at Scale, January 10-12, 2024. Communication of statistical findings, in addition to the computational procedures used to reveal them, is an important practice we want to teach our students. However, evaluating the quality of student work and providing feedback on the kind of open-ended assignments and projects that can build communication skills can be time consuming for an instructor. How can we evaluate communication products fairly and give feedback more efficiently? How can we learn from other writing pedagogies to inform our efforts? This workshop aimed to cross-pollinate ideas from teaching writing across multiple disciplines.

This workshop had 28 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Yue Jiang	Duke University, Statistical Science
Sara Stoudt	Bucknell University, Mathematics
Speakers	Affiliation & Department

Jonathan Auerbach	George Mason University, Statistics
David Brown	Carnegie Mellon University, English
Mine Çetinkaya-Rundel	Duke University, Statistical Science
Amber Dood	University of Michigan, Sweetland Center for Writing
Shannon Ellis	University of California, San Diego, Cognitive Science
Solaire Finkenstaedt-Quinn	University of Michigan, Sweetland Center for Writing
Suguru Ishizaki	Carnegie Mellon University, English
Yue Jiang	Duke University, Statistical Science
Michael Laudenbach	Carnegie Mellon University, English
Amelia McNamara	University of St. Thomas, Computer and Information Sciences
Ramona Naddaff	University of California, Berkeley, Rhetoric
Suraj Rampure	University of California, San Diego, Halıcıoğlu Data Science Institute
Kelly Spoon	San Diego Mesa College, Mathematics
Maria Tackett	Duke University, Statistical Science
Allison Theobold	California Polytechnic State University, San Luis Obispo, Statistics

Participant comments on the workshop included the following:

- *It was a small but collegial group of people that spanned a variety of disciplines. I learned a lot from both the presentations and informal chats over meals and between sessions.*
- *I loved hearing about what others did in the classroom - I'm inspired to use some of their ideas in my own teaching practice. I also loved meeting the other participants!*
- *That there's a rich community of statistics and data science educators that I should try and work with more closely!*

Decision Making and Uncertainty, February 5-9, 2024

IMSI hosted the reunion workshop, Decision Making and Uncertainty, February 5-9, 2024, as a follow up to the 2022 long program on Decision Making and Uncertainty. The aim was to bring together a group of participants who were speakers and long-term participants in the Spring 2022 long program, and discuss the progress and developments made since in the areas they presented and the collaborations that started at IMSI. The workshop cov-

ered methodological advances in: 1) decision making under uncertainty and reinforcement learning, 2) model uncertainty and robustness, 3) sustainable finance and systemic vulnerabilities, 4) machine learning and automated markets, and 5) financial stability and stress testing.

This workshop had 73 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Rama Cont	University of Oxford, Mathematical Institute
Jan Obloj	University of Oxford, Mathematical Institute
Thaleia Zariphopoulou	University of Texas, Austin, Mathematics
Speakers	**Affiliation & Department**
Beatrice Acciaio	ETH Zürich, Mathematics
Jose Blanchet	Stanford University, Management Science and Engineering
Igor Cialenco	Illinois Institute of Technology, Applied Mathematics
Samuel Cohen	University of Oxford, Mathematical Institute
Paul Glasserman	Columbia University, Business School
Xin Guo	University of California, Berkeley, Financial Modeling, and Industrial Engineering and Operations Research
Lars Hansen	University of Chicago, Economics
Anran Hu	University of Oxford, Mathematical Institute
Thibaut Mastrolia	University of California, Berkeley, Industrial Engineering & Operations Research
Andreea Minca	Cornell University, Operations Research and Information Engineering
Marcel Nutz	Columbia University, Statistics
Huyên Pham	Université Paris Cité, Laboratoire de Probabilités, Statistique et Modélisation
Christoph Reisinger	University of Oxford, Mathematical Institute
Ludovic Tangpi	Princeton University, Operations Research and Financial Engineering
Peter Tankov	ENSAE Paris, Quantitative Finance

Luitgard Veraart	London School of Economics and Political Science, Mathematics
Ruodu Wang	University of Waterloo, Statistics and Actuarial Science
Johannes Wiesel	Carnegie Mellon University, Mathematical Sciences
Renyuan Xu	University of Southern California, Engineering
Luhao Zhang	Columbia University, Industrial Engineering and Operations Research
Yufei Zhang	Imperial College London, Mathematics
Xunyu Zhou	Columbia University, Industrial Engineering and Operations Research

Participant comments on the workshop included the following:

- *It provided an opportunity to meet with the researchers and experts working in the field of Uncertainty and Decision Making; and share the latest research and explore new ideas. It also provided an opportunity to reinsure the importance of collaboration among the professionals and excel the knowledge sharing.*
- *The biggest takeaway is new level of energy and motivation to work in this very important area of Decision Making and Uncertainty, because it help us to better deal with the ever-changing real-world problems and to control and limit the risk.*

Computational Challenges and Optimization in Kinetic Plasma Physics, February 19 - 22, 2024

IMSI hosted the workshop, Computational Challenges and Optimization in Kinetic Plasma Physics, February 19-22, 2023. Nuclear fusion holds immense promise as a source of clean, safe, and sustainable energy. Critical to the development path for fusion are cutting-edge capabilities in computer simulations, computer-aided design, and optimization. While recent advances in simulations, multi-scale analysis, PDE-constrained optimization, global optimization, and machine learning have been transformative for the fusion field, characterization of kinetic plasma physics and associated transport processes remains a grand challenge when it comes to advancement of fusion reactor designs. This workshop brought together computational physicists and applied mathematicians to establish and foster active interdisciplinary collaboration to address computational challenges and optimization in kinetic plasma physics.

This workshop had 68 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Antoine Cerfon	Type One Energy Group, Inc.
Lukas Einkemmer	University of Innsbruck, Mathematics
Qin Li	University of Wisconsin, Madison, Mathematics

Genia Vogman	Lawrence Livermore National Laboratory
Speakers	Affiliation & Department
Emily Belli	General Atomics, Magnetic Fusion Energy
Russ Caflisch	New York University, Mathematics
Luis Chacon	Los Alamos National Laboratory, Applied Mathematics
Andrew Christlieb	Michigan State University, Mathematics
Nicolas Crouseilles	INRIA
Ionut Farcas	University of Texas, Austin, Oden Institute for Computational Engineering and Sciences
Cary Forest	University of Wisconsin, Madison, Physics
Ilon Joseph	Lawrence Livermore National Laboratory, Physics
James Juno	Princeton Plasma Physics Laboratory
Noah Mandell	Princeton Plasma Physics Laboratory
Lorenzo Pareschi	Heriot Watt University, Mathematics
Elizabeth Paul	Columbia University, Applied Physics and Applied Mathematics
Jing-Mei Qiu	University of Delaware, Mathematical Sciences
Lee Ricketson	Lawrence Livermore National Laboratory
Mark Sherlock	Lawrence Livermore National Laboratory
Uri Shumlak	University of Washington, Aeronautics & Astronautics
Paul Terry	University of Wisconsin, Madison, Physics
Li Wang	University of Minnesota, Twin Cities, Mathematics
Erika Ye	Lawrence Berkeley National Laboratory
Poster Presenters	Affiliation & Department
Fabio Cassini	University of Verona, Computer Science
Peiyi Chen	University of Wisconsin, Madison, Mathematics
Jack Coughlin	University of Washington, Applied Mathematics
Pranab Deka	KU Leuven, Plasma-astrophysics
Hamad El Kahza	University of Delaware, Mathematical Sciences
Federica Ferrarese	Università degli studi di Ferrara, Computer Science
Andrew Ho	Lawrence Livermore National Laboratory
Antoine Hoffmann	EPFL (Ecole Polytechnique Fédérale de Lausanne), Physics

Milan Holec	Lawrence Livermore National Laboratory
Dimitrios Kaltsas	University of Ioannina, Physics
Guillaume Le Bars	EPFL (Ecole Polytechnique Fédérale de Lausanne)
Jiaxing Liang	University of Maryland, College Park, Mathematics
Martina Prugger	Max Planck Institute for Plasma Physics
Stefan Schnake	Oak Ridge National Laboratory
Kai Schneider	Aix-Marseille Université, Mechanics and Applied Mathematics
Rostislav-Paul Wilhelm	RWTH Aachen University, Applied and Computational Mathematics
Yukun Yue	University of Wisconsin, Madison, Mathematics

Participant comments on the workshop included the following:

- *As an experimentalist, I enjoyed being exposed to the mathematical rigor.*
- *Networking. The workshop brought together a diverse group of participants. As a non-physicist, I had the great pleasure to interact with physicists and discuss about potential future collaborations.*
- *The auditorium is perfect; the audio and visual aids greatly enhance the focus on the scientific content. The panel with industry representatives was an uncommon but highly interesting moment of the workshop.*
- *Diversity of scientific background of participants. Nice to interact with talented young people.*
- *The industry panel and the opportunities for discussions.*
- *Getting mathematicians engaged in developing fusion energy is important.*
- *Applied mathematicians have a lot of work to do to help plasma physicists bring fusion closer to a commercialization.*
- *Combining the technical expertise of engineers, physicists, and mathematicians allows open-minded researchers to successfully tackle the most challenging problems.*
- *In terms of opportunities, I gained insight into what start-ups working in fusion expect from a candidate. This will help me give better guidance to my students if they opt for a career in industry. I also learned many new challenges people working in applications have that require developing new mathematical ideas.*
- *I want to thank the staff and organizers. I am in a tenure-track position and this workshop greatly influences my career by making new connections and starting new lines of research. The staff was amazingly supportive!*

Methods for Solving and Analyzing Dynamic Models in the Face of Uncertainty and Cross-sectional Heterogeneity, March 7 - 8, 2024

IMSI hosted the workshop, Methods for Solving and Analyzing Dynamic Models in the Face of Uncertainty and Cross-sectional Heterogeneity, March 7-8, 2024. This workshop

brought together researchers to explore methods for solving and analyzing dynamic economic models in the face of uncertainty and cross-sectional heterogeneity. The program featured economic model builders and researchers from applied mathematics with complementary interests. Participants explored recent developments and applications of tech niques designed to support the study of models with diverse economic agents that confront idiosyncratic and aggregate uncertainties. Workshop participants considered the consequences of broad notions of uncertainty and confronted the so-called “deep uncertainties” that prevail in many applications. This workshop was organized in collaboration with the Macro Finance Research Program at the University of Chicago.

This workshop had 40 unique participants, including speakers and organizers.

Organizers	Affiliation & Department
Fernando Alvarez	University of Chicago, Economics
Lars Peter Hansen	University of Chicago, Economics
Takis Souganidis	University of Chicago, Mathematics
Speakers	Affiliation & Department
Adrien Auclert	Stanford University, Economics
Anmol Bhandari	University of Minnesota, Twin Cities, Economics
Ruimeng Hu	University of California, Santa Barbara, Mathematics, Statistics and Applied Probability
Daniel Lacker	Columbia University, Industrial Engineering and Operations Research
Pierre-Louis Lions	Collège de France, Mathematics and Computer Science
Nizar Touzi	New York University, Finance and Risk Engineering
Thaleia Zariphopoulou	University of Texas, Austin, Mathematics

Participant comments on the workshop included the following:

- *The magnificent speakers. I was also invited to have dinner with some of the people whose work I admire the most in the profession and it was great to learn more from them in that setting!*
- *Macroeconomists and mathematicians have a lot to learn from each other.*
- *The importance of enhancing communication between these two "communities" if you will. There are many exciting and important topics on which we can work together.*

New Approaches to Ecological Dynamics of Microbial Communities, April 29 - May 3, 2024

IMSI hosted the workshop, New Approaches to Ecological Dynamics of Microbial Communities, April 29 – May 3, 2024. Co-hosted with the National Institute for Theory and Mathematics in Biology. To foster discussions on these themes, the organizers chose a problem-centric format: instead of a long series of research talks, participants succinctly presented open problems in the field, which were then discussed by the whole group and in smaller breakout sessions.

IMSI funded 20 participants.

Organizers	Affiliation & Department
Stefano Allesina	University of Chicago, Ecology and Evolution
Luis Amaral	Northwestern University, Chemical and Biological Engineering
Seppe Kuehn	University of Chicago, Ecology and Evolution
Speakers	Affiliation & Department
Martina Dal Bello	Yale University, Microbial Sciences Institute
Karna Gowda	Ohio State University, Microbiology
Jiliang Hu	Massachusetts Institute of Technology (MIT), Physics
Terry Hwa	University of California, San Diego (UCSD), Physics
Britt Koskella	University of California, Berkeley, Integrative Biology
Maria Rebolleda-Gomez	University of California, Irvine, Ecology & Evolutionary Biology
Alexander Strang	University of California Berkeley, Statistics
Mikhail Tikhonov	Washington University in St. Louis, Physics
Christine Ziegler	Massachusetts Institute of Technology (MIT), Civil and Environmental Engineering

Participant comments on the workshop included the following:

- *The workshop inspired me to get to know some potential collaborators in ecology.*
- *I appreciated that some [of the presentations] were very pedagogical.*
- *I liked the mixture of high-level/pedagogical stuff and research projects.*
- *The workshop inspired me to learn more linear algebra, collaborate with theoreticians, and collaborate to phenotype more bacteria and try to find physiological patterns.*
- *The workshop inspired me to think about as an experimentalist how to generate data that is useful for modelers/theorists.*

3.4 Other Short Research Events

Climate Tipping Phenomena in Non-autonomous Paleoecosystems (Interdisciplinary Research Cluster), June 20-30, 2023

This Interdisciplinary Research Cluster (IRC) developed a conceptual theoretical framework for the understanding and qualitative (and potentially quantitative) description of tipping points and regime shift in a coupled global climate-biota system taking into account the temporal heterogeneity of the processes involved, in particular the effect of timing of the potential extinction triggers. There is some evidence in the fossil records that the global ecosystems' response to such a trigger (e.g. a bolide collision) can be diverse, leading to a considerable biodiversity loss in one case but having a relatively small effect in another. However, any consistent theory for an understanding of the mentioned variability is entirely lacking. This IRC bridged this gap. This IRC continued past efforts (at MBI, NIMBioS, and ICERM) in shaping an interdisciplinary community to develop an emerging agenda on the implementation of modern mathematical methods of modeling and data analysis to better understand the mechanisms of mass extinction events in Earth history.

This IRC had a total of 10 participants.

Participants	Affiliation & Department
Luís Bettencourt	University of Chicago, Mansueto Institute for Urban Innovation
Punit Gandhi	Virginia Commonwealth University
Pincelli Hull	Yale University, Planetary and Earth Sciences
Rowan Lockwood	College William & Mary, Geology
Corinne Myers	University of New Mexico, Earth and Planetary Sciences
Sergei Petrovskii	University of Leicester, School of Computer and Mathematical Sciences
Martin Rasmussen	Imperial College London, Mathematics
Daniel Rothman	Massachusetts Institute of Technology (MIT), Earth, Atmospheric, and Planetary Sciences
Ivan Sudakow	The Open University, Mathematics and Statistics
Hao Helen Zhang	University of Arizona, Mathematics

Co-Creating a Community Data Visualization Tool with Community Partners (Interdisciplinary Research Cluster), May 20-31, 2024

This Interdisciplinary Research Cluster (IRC) completed and disseminated an online data visualization tool to be used by community members in the Olneyville neighborhood of Providence, RI. The tool, called VECINA (Visualizing Environmental and Community Information for Neighborhood Advocacy, Spanish for "Neighbor"), is built on top of a neighborhood map, and includes layers with data concerning environmental and flooding prob lems, health care resources, and K-12 education. The resulting webpage will be in both English and Spanish, and will provide community members with access to their own neighborhood data that they can use to advocate for policy changes as well as make indi vidual decisions. In addition to quantitative data, the layers include narratives that provide the context, a critical element that is often missing in similar tools.

The IRC included a mix of technical experts and members of the community that the tool will serve. The partnership was facilitated by *Nuevas Voces*, a leadership development program in Olneyville sponsored by the Woonasquatucket River Watershed Council (WRWC). In addition to completing the tool, an outcome of this IRC will be the collaborative process that led to its development. Upon completion, the tool will be handed over to WRWC and *Nuevas Voces*.

The IRC had a total of 11 participants.

Participants	Affiliation & Department
Carrie Diaz Eaton	Bates College, Computer Science
Jing Fang	Bates College, Economics and Mathematics
Bekah Greenwald	Woonasquatucket River Watershed Council
María José Gutierrez	Woonasquatucket River Watershed Council
Joseph Hibdon	Northeastern Illinois University, Mathematics
Jenny Mercado	Woonasquatucket River Watershed Council
José Pabón	New Jersey Institute of Technology, Mathematics
Adriana Pastor Almirón	Bates College, Biology
Victor Piercey	Ferris State University, Mathematics
Kiara Sanchez	College of the Holy Cross, Mathematics and Computer Science
Bianca Thompson	Westminster University, Mathematics

3.5 SUMSA

The Summer Undergraduate Mathematics and Statistics Accelerator (SUMSA) is an eight-week mathematics and statistics summer bootcamp for undergraduates at U.S. col leges and universities. SUMSA was hosted by IMSI on the campus of the University of Chicago, June 12 – August 4, 2023. The aim of the program is to help prepare students for the rigors of graduate school in a mathematical science via lecture series and problem sessions taught by experienced postdocs and advanced graduate students from the University of Chicago. The primary focus of this bootcamp was basic coursework. SUMSA of fered an avenue for "standardizing" the backgrounds of undergraduates to help them develop competitive candidacies for graduate school. The topics covered included:

- Linear algebra: real and complex vector spaces (including infinite-dimensional ones) linear transformations, bases and dimension, algebra of linear transformations, invertibility of linear transformations and isomorphism of vector spaces, determinants, positive-definite inner products, symmetric and orthogonal linear trans formations and projections, singular value decompositions
- Topology of metric spaces: continuous functions, open, closed, compact, and connected sets, convergence of sequences, completeness, Heine-Borel, Bolzano Weierstrass, Banach Fixed Point Theorem
- Advanced calculus: differentiability of functions in R^n, critical points and constrained extrema, vector fields and flows, Inverse and Implicit Function Theorems. Integration in several variables, Fubini's Theorem, Change of Variables Formula, Stokes' Theorem with special cases in low dimensions
- Probability: Overview of probability models for random phenomena, independence and dependence, distribution theory, probability inequalities and limit theorems, probabilistic foundations of statistical inference, Bayes rule and diagnostic testing
- Statistical modeling: Linear and non-linear models, regression analysis, categorical data analysis, basics of inference
- Data science: Data structures, missing and irregular data, regression analysis and supervised learning, training, testing and cross validation for performance evaluation, optimization

The weekly schedule included two lectures per day on Monday-Thursday, and problem sessions on Fridays.

Participants received travel support and housing on the University of Chicago campus, and a stipend.

SUMSA 2023 had 25 participants.

Participant comments on the workshop included the following:

- *Meeting peers that were excited about math.*

- *While I enjoyed the courses, my favorite moments were with the people there. I liked hanging-out and making friends and getting to explore the city with them.*
- *I would say my favorite experience was just getting to know like-minded people. It was nice sort of feeling like I was in a bubble just learning math and enjoying doing so with other people.*
- *I loved going out into the city with my classmates. Taking the same courses and struggling on similar material with everyone around you forms a very powerful bond between people. This program resulted in some lifelong friendships.*
- *My biggest takeaway from SUMSA was that no matter how difficult the material got or how lost I felt in a course, continuing to try my best to understand the concepts and do the homework helped a lot.*
- *It's a great summer where I could learn without worrying about financial burdens, and it was my first time ever away from home and live on my own. It's a valuable experience.*
- *Math is not a spectator sport.*
- *It was cool seeing how all the different classes fit together. I've never taken that many math classes at the same time, so making connections between them was helpful.*
- *I thought this program was as advertised. It was intensive and covered most of the mentioned material. I got to know many great people as a result of attending this program, and it strengthened my interest in mathematics. I'm grateful I got to attend this program. Thank you.*

3.6 IMSI Summer Internship Program

The IMSI Summer Internship program is a workforce development effort to accelerate the preparation of PhD students in the mathematical sciences for careers in interdisciplinary and translational research, in industry, and in government laboratories by providing them with broadening professional experiences. Six interns (three women and three men) were selected from a national pool of over 100 applicants from PhD programs in mathematics, statistics, and related mathematical sciences.

The interns began with two weeks of intensive training participating in the IMSI Data Science Bootcamp, offered online via Zoom May 27 – June 10, 2023. The bootcamp was led by an expert in data science and engineering. The training was a full time, interactive experience with lecture material available in advance, hands-on daily group work, and group instruction with the opportunity to interact with other interns. The aim was to provide highly capable PhD student interns with a jump start into data science, machine learning, model ing, and analysis to enhance success in their interdisciplinary internship appointments. In anonymous surveys following the boot camp, interns indicated a high degree of satisfaction with the relevance, range of topics, and their overall experience. They felt they received a level of material that was not available in their academic training, and they enjoyed the experience of coming together to work with different members of the group.

The internship placements lasted for eight weeks, from June 10 to August 16, 2023 (about 2 months). Interns were placed individually or in teams depending on the scope of host projects and their mentorship capacity. Interns completed necessary onboarding for the host and were embedded in labs or groups at the host institution with a lead investigator as their direct supervisor and project mentor. Upon completion of the internship, participants authored brief technical reports in the format of a scientific paper to describe their project. Hosts expressed enthusiasm for the work the interns were able to do for them. In some cases, the laboratories had not previously engaged graduate students from the mathematical sciences and were pleased with what they were able to accomplish for them. At least one intern reported that their project was leading to ongoing collaboration, and another reported that their industry internship was extended by the company through the next academic year. Post-internship surveys indicated strong agreement with the statement, “I would recommend the IMSI internship program to future interns.”; in fact, every participant chose “strongly agree” with that statement.

Participant home institutions and graduate degree programs:

Participant Home Institution	Participant PhD Degree Program
Northern Illinois University	Mathematics
Ohio State University	Mathematics
University of Chicago	Mathematics
University of Oregon	Mathematics
University of Kentucky	Statistics
University of Illinois	Statistics

Internship host organizations:

Internship Host Organization	Area
Ameren Innovation Center	Retirement Propensity Scoring and Milkweed Image Detection
University of Illinois at Chicago Bioengineering	Geometric topology, persistent homology, phase transitions and the human brain
University of Illinois at Urbana-Champaign Biochemistry (x2, joint project)	Spatial relationship models of amino acids inside protein structures with the long-term goal of predicting 3D structures
University of Illinois Ecology	Exploration on nitrous oxide emission
Wolfram Research	Extraction of Mathematical Statements from ArXiv submissions

3.7 Special Events

Career Paths in the Mathematical Sciences, June 8-9, 2023

Career Paths in the Mathematical Sciences was jointly organized by IMSI, the Math Alliance, the Institute for Mathematics and its Applications. This workshop gave undergraduates who are planning to enter graduate programs in a quantitative science (e.g. math, applied math, statistics, biostatistics, data science, financial mathematics, etc.) an understanding of a variety of application areas and career paths in the mathematical sciences. Student participants were nominated to attend by their faculty mentors who agreed to guide them through the process of applying to graduate programs. Students and mentors were invited to attend. The workshop included plenary lectures, panel discussions, active learning modules, networking opportunities, and social events.

Career Paths had a total of 73 participants, including organizers, speakers, and panelists.

Organizers	Affiliation & Department
Nitsan Ben-Gal	3M
Kevin Corlette	IMSI and the University of Chicago
David Goldberg	Purdue University, Mathematics
Javier Rojo	Indiana University, Epidemiology and Biostatistics
Padmanabhan Seshaiyer	George Mason University, Mathematical Sciences
Daniel Spirn	Institute for Mathematics and its Applications (IMA), University of Minnesota; Mathematics
Speakers, Panelists, & Plenary Speakers	Affiliation & Department
Sven Leyffer	Argonne National Laboratory, Mathematics
Rebecca Willett	University of Chicago, Statistics, Computer Science, and Data Science Institute
Jacob Bond	GM
Jim Harmon	Liberty Mutual
Holly Wiberg	Flatiron Health
Kathy Ensor	Rice University, Statistics
Ramon Durazo-Arvizu	Children's Hospital Los Angeles and the University of Southern California (USC), Pediatrics
Adrian Coles	Bristol-Myers-Squibb
Miriam Nuño	University of California, Davis (UC Davis)
Jenny Yang	Apple
Steve Sain	Jupiter Intelligence
Brian Boonstra	Jump Trading
Robert Bridges	Oak Ridge National Laboratory (ORNL)
Emil Constantinescu	Argonne National Laboratory
Bridget Manning	Amazon

Govanni Grandos	Purdue University, Mathematics
Whitney Mgbara	University of California, Berkeley (UC Berkeley)
Quindel Jones	Virginia Commonwealth University, Applied Mathematics

Participant comments on the workshop included the following:

- *Meeting so many people in industry. I have not had many opportunities to talk to people with degrees in math that are working in industry. I also loved that the panelists include black women.*
- *I liked being able to network and talk with different people who were attending. As well as the improv activity was beyond helpful. I really liked it.*
- *I enjoyed how everyone at the conference was welcoming and was comfortable enough to talk to each other, especially during the breaks. I enjoyed the guest speakers and hearing about their different backgrounds. I also really appreciated the diversity of the group who was in the conference.*
- *My highlight of the conference was sitting down and talking to other mentors and getting advice while sharing my own experiences. I made several connections.*
- *To learn more from people who have done it before and are helping me by informing me of opportunities.*

BRING MATH: Bridges for the Next Generation: Mathematical Science Research and Our Future, October 5-6, 2023

BRING MATH (**BRI**dges for the **N**ext **G**eneration: **MATH**ematical Science Research and Our Future) was a two-day conference for undergraduates interested in the mathematical sciences. It was a collaboration between IMSI and the Mathematics and Computer Science Division at Argonne National Laboratory, and was hosted at Argonne, which is located in Lemont, Illinois.

BRING MATH had multiple purposes: 1) expose students and faculty to research in the mathematical sciences at Argonne, and to help them understand its real world applications, 2) increase students' interest in the mathematical sciences and broaden their access to opportunities to pursue that interest, 3) diversify the mathematical science community, 4) educate students about summer opportunities available to them, and 5) help students learn about career opportunities in the mathematical sciences and how to pursue them.

BRING MATH included the following activities: 1) dedicated sessions on topics such as climate change, data & information, and quantum computing & information, 2) tours of Ar gonne facilities such as the Advanced Photon Source, the Rapid Prototyping Laboratory, and Argonne's supercomputing center, 3) networking opportunities with researchers at Argonne, and 4) a panel on career paths in the mathematical sciences.

IMSI supported 43 participants.

Participant comments on the conference included the following:

- *My favorite moment when three panelists shared their experiences with imposter syndrome and that they make many mistakes and failures every day. They said it is from those failures to immediately get everything right that they learn something new.*
- *Most of us attending the conference, as undergraduate math majors, have little to no experience in industry, math-related work. It was great to be able to ask a lot of questions about the researchers' paths and experiences.*
- *My favorite experience was being able to meet and speak to so many individuals with similar aspirations as me and similar concerns.*
- *I most enjoyed seeing science being done on the tours.*
- *The fact that we got an opportunity to talk face-to-face with the great minds on each STEM field. Also, the fact that we got to see their working environment and the cutting-edge technology they use to achieve their goals.*
- *Seize opportunity, a lot of people talked about great success and struggles but the constant was working hard and taking opportunities when they presented themselves.*
- *My biggest takeaway is that it is ok to make mistakes, and to not know exactly how your life will turn out. Its impossible to know exactly where your quest and questions will lead you.*
- *This was one of the most fire-lighting events I have ever experienced in my own experience in mathematics. I will hope today is not my last day at a National Laboratory, hopefully not my last at Argonne either.*
- *Thank you to everyone who worked to put BRING MATH together. It has truly impacted my view of graduate school and has encouraged me to pursue higher education.*

Modern Mathematics Workshop, October 25-26, 2023

The Modern Mathematics Workshop (MMW) was a two-day workshop which took place in conjunction with the 2023 NDiSTEM Conference of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS). It showcased contemporary research happening at NSF-funded mathematical sciences institutes around the country. It grew out of a similarly named yearly event originally organized by MSRI and first held at Howard University in 2002. It became a collaboration with SACNAS in 2006 and has been jointly organized by the Mathematical Sciences Institutes since 2008. Since 2011 this event has been funded by the NSF through the Mathematical Sciences Institutes Diversity Initiative. In 2023, IMSI is the lead organizer for the MMW. The workshop was a mix of ac tivities including research expositions aimed at graduate students and researchers, mini-courses aimed at undergraduates, a keynote lecture by a distinguished scientist, and a re ception where participants can learn more information about the Mathematical Sciences Institutes. MMW encourages undergraduates from underrepresented groups to pursue careers in the mathematical sciences, and builds research and networking opportunities among undergraduates, graduate students and recent PhDs.

The Modern Mathematics Workshop had a total of 75 participants, including speakers.

Speakers	Affiliation & Department
Vrushali Bokil	Oregon State University, Mathematics
Daniela Ferrero	Texas State University, Mathematics
Claudio Gómez-Gonzáles	Carleton College, Mathematics and Statistics
Fernando Granha Jeronimo	Simons Institute and Institute for Advanced Study
Johnny Guzman	Brown University, Applied Mathematics
Jose Israel Rodriguez	University of Wisconsin, Madison, Mathematics
Marco Martinez	North Central College, Mathematics and Actuarial Science
Alejandro Morales	University of Massachusetts Amherst, Mathematics and Statistics
Juanita Pinzón-Caicedo	University of Notre Dame, Mathematics
Alicia Prieto Langarica	Youngstown State University, Mathematics & Statistics

3.8 Education Outreach

Education Outreach Programs at UChicago

IMSI supports and provides partial funding for three education outreach programs run out of the UChicago Math Department: the Young Scholars Program (focused on pre-college students), and the Polk Bros & SESAME programs (targeted at math teachers, mainly grades 3-8).

Polk Bros.

The Polk Bros. program has as its mission the improvement of the teaching of mathemat ics in the Chicago Public Schools. This is accomplished by giving classes to teachers in the CPS during the summer and academic year. This past summer, starting in the last week of June 2023, Professor John Boller gave a course featuring a modern method of teaching mathematics known as the Open Approach. The idea of this method is to present simple looking problems which represent important mathematical themes and ask students (in this case the CPS teachers) to solve them in as many different ways as possi ble. This shows the teachers that mathematics is not a memory game, but a beautiful cre ative subject with many applications. The class ran for five weeks, Monday-Thursday from 9am to noon. Due to the large class size, it was given remotely to the teachers.

A second course, also starting the last week of June was given by Professor Bob Feffer- man, and it was a content course whose subject was Algebra. The teaching method of this class emphasized participation by the teachers, and it also had as a fundamental part of its mission, showing the teaches the beauty of mathematics, and getting them away from memorizing rules, and instead allowing them to gain a deep understanding and ap- preciation of the material. This class ran for four weeks, Monday-Thursday from 1:30pm to 4:30pm. The course was also given remotely. Professor Fefferman then began, in the fifth week, a new content class featuring an interesting approach to Number Theory. It was continued by holding ten three-hour sessions on Mondays of the following academic year.

Number of Participating Teachers, Summer 2023 and the following academic year:

Methods Course: 84
Algebra Course: 113
Number Theory: 83

The following quotes are taken from evaluations given by participating teachers:

This was an excellent course! Dr. Boller truly embraced the “open approach” which made it easy to enter the discussions. Initially, I had trepidations about my ability to keep up with this course - I hadn’t practiced higher level concepts since I was in high school, when, for me, math classes were stressful and confusing. Dr. Boller really broke down concepts in a way that allowed me to stretch some of those math muscles that had been lying dormant for so long. His approach allowed for discovery and creative conceptual thinking, explor- ing different points of entry and a spirit of play with numbers. This made for a fun and en- gaging journey through a deeper level of understanding various math concepts.

This course has affected the way I will teach math this coming year in several ways.First and foremost, I will have students work through proofs, as I think this is a very thought-pro- voking way for my mathematicians to learn. In addition, I believe they will really love the ruler game. It is a fun way to teach prime factors, GCD, LCM, etc. This game can also be modified for all levels of instruction. Moreover, many of the concepts and strategies I

learned in this class can be differentiated for all learners. Finally, I can't wait to teach my students about Modular Arithmetic. It is a unique way of thinking about numbers and how to manipulate them according to the mod you are working in. Overall, I am excited about what my students can learn and do this coming school year.

I wish the Polk Bros. Program can continue to provide the great opportunity for CPS teachers to develop their teaching skills and gain insight into their content areas. I really appreciate the Polk Bros program providing the opportunity for me to learn courses this summer.

This Polk Brothers course has aided in refreshing my Algebra content knowledge. I have taught 3rd grade for 13 years and do not visit secondary level Algebra often during math class. Because of this, I have forgotten much of the Algebra content. This course will greatly affect the way I teach math by providing me ideas and methods of teaching Algebra in Middle and Secondary Schools.

I spent many hours teaching my students the math "rules" to follow to solve math problems. Dr. Boller explained the rules. He explained why these rules exist. The theorems behind the rules. There were so many times that I literally had my mind blown during this class. (I know many others did too) I wish Dr. Boller could come to grammar schools and do workshops with junior high students to discuss some of the more important math concepts. For example, the way he explained absolute value. The phrases he used that made it all 'click' for me. I don't know that I can ever teach a lesson as well as he did but I am definitely inspired.

These courses will significantly affect the way I teach math. The classes have helped me understand concepts that I only knew because of doing the algorithm. It is great to understand why the properties of mathematics are valid. The professors have modeled different ways to approach a problem which will help me also model this to my students. The professor designed various problems that made mathematics more approachable for everyone. I plan to use some of his problems with my students and help them engage in mathematics.

SESAME

In 2023-24, the SESAME program continued to operate by offering classes that made up part of the Algebra Initiative project in collaboration with the Chicago Public Schools (CPS), DePaul University, and the University of Illinois at Chicago (UIC). The Algebra Initiative is a program through which teachers take courses from the University partners so as to be able to offer a 9th grade algebra course to qualified students in the 8th grade. It includes teacher training as well as a qualifying exam. Students who then take a year-long course from a qualified teacher take an exit exam, and if they pass, they are not required to take an Algebra I course in 9th grade.

In the Autumn, Winter, and Spring Quarters at the University of Chicago, respectively, the Algebra I, II, and III courses were offered in a hybrid remote/in-person format (alternating

weeks between each type), with total enrollments of 23, 24, and 23, by quarter. In all three quarters, the full roster consisted of full-time CPS teachers.

Young Scholars Program

In the Summer of 2023, the Young Scholars Program (YSP) was held in an in-person for mat. YSP is a four-week summer program for mathematically talented 7th through 12th graders, divided into three grade-level cohorts: 7-8, 9-10, and 11-12. Each cohort had two associated faculty instructors who taught classes and a number of undergraduate counselors who ran break-out sessions. In 2023, we had a grand total of 68 students who participated, the vast majority of whom attended the Chicago Public Schools. They divided into cohorts of 31, 19, and 18, respectively. We had 6 faculty instructors and 16 undergraduate counselors. The theme for 2023 through all of the cohorts was geometry.

Education Outreach Programs at the University of Illinois at Chicago

In 2023, the YSP ran four one-week sessions:

- Number Theory and Cryptography (July 10 – July 14, 2023)
- Graph Theory and Combinatorics (July 17 – July 21, 2023)
- Algorithms and Data (July 24 – July 28, 2023)
- Applied Mathematics and Modeling (July 31 – August 4, 2023)

The daily schedule included a morning lecture, guided exercise sessions based on the day's lecture, a lunch break, work on group projects, and either a guest lecture or panel or a special large group activity. Students could attend as many weekly sessions as desired, and we had 40 to 50 participants each week (with more than 80 total participants). In each week approximately two-thirds of the students were rising 9th and 10th graders; the youngest students were rising 8th graders and the oldest had just graduated from 12th grade.

Students came from high schools all around the city, both public and private, but the vast majority were from Chicago Public Schools. The program was completely free to participate in, lunches were provided, and UIC is easily accessible by public transport which made the program accessible for many students around the city. Additionally, there were no mathematical prerequisites to participate; the lectures, exercises, and group projects were designed to be approachable and interesting to students with a wide variety of math ematical backgrounds. Students could choose which exercises to pursue and the direction of their group projects, and the graduate student instructors did a great job of making the program exciting and enriching for all the students. Seventy-six participants filled out the summary survey on their final day. Of those that chose to fill out the demographic questions, we had 43% female;14% Hispanic; and 50% Asian, 21% White, 19% Black or African American, and 3% American Indian or Alaska Native. (Almost 6% chose more than one category.)

In 2023, the YSP program again partnered with Math Circles of Chicago (MC^2) to reach a wider audience of students across the city. Students who participated in a Math Circles program during the school year could register for the YSP from their Math Circles account, and Math Circles publicized the program to their students and teachers in the spring. The YSP summer program complemented Math Circles summer programs which focused on middle school students, and together the two summer programs offered opportunities to all Chicago students from rising 6th grade through graduating seniors.

3.9 Communication and Engagement

IMSI Communications Bootcamps

Concept

As part of IMSI's mission to improve communication within the mathematical and statistical fields, IMSI offers a series of bootcamps to help early career researchers develop their communication skills. The bootcamps, offered online and in person, build skill sets applicable to academic careers and individuals' broader communication goals. When participants complete all four sessions, they qualify for recognition of their work through a LinkedIn badge.

Set of Topics Covered

Communicating Mathematics to a Technical Audience:
Most of the core communication tasks for researchers in the mathematical sciences will be focused on reaching audiences consisting of other professionals within the Science, Technology, Engineering, and Mathematics (STEM) fields. In this workshop, participants discuss the different types of technical audiences they may wish to communicate with, de velop skills for reaching those audiences across different technical communication modes, including research articles and presentations, critically appraise a range of different technical communications, and develop a set of best practices.

Communicating Mathematics to a General Audience:
There are many different reasons a researcher in the mathematical sciences may want to communicate with a general audience: for example, they may want to increase engagement in mathematics, spread the word about their research, or impact how statistics influ ences policy decisions. This workshop develops skills that will help mathematical scientists communicate with any audience no matter their reason. Participants appraise what communication methods work for which goals, discuss jargon and the importance of finding the right amount for a given audience, and engage with the power and danger inherent in discussing numbers in the media.

Telling Your Mathematical Story:
Storytelling and narrative are one of the most powerful tools available to engage any audi ence with a topic, especially more technical topics like those found in the mathematical sciences. In this workshop, participants are introduced to core storytelling aspects like characters, events, and narrative structure. They also take part in several hands-on activi

ties where they are guided through the process of taking their research from a set of facts to a full-fledged story.

Getting Your Mathematics Out There:
The process of getting research into a journal or a conference is one thing, but getting it into the hands of the wider public is something else entirely. This workshop shows mathe matical scientists how to do just that. Participants learn how to work with the media to tell their story, and how to share it themselves. They also take part in activities where they draft the start of their own press release and learn how it feels to be interviewed and to in terview.

Current Impact
The Mathematical Communication Bootcamps were re-designed at the start of 2024 and the first three sessions of the newly designed series have been offered once since then. This partial run has had a total of 19 unique participants, with four participating in all of them.

MathStatBites

Concept
MathStatBites is a mathematical and statistical research blog, written by early career researchers and students in those fields to translate peer-reviewed journal articles for a non-specialist audience. There is significant interest from early career researchers who want to learn how to write accessible summaries of research for their peers and colleagues who are not experts in a particular area of research, as well as for broader audiences outside the fields of mathematics and statistics. This educational blog, MathStatBites, provides translations of research into digestible “bites,” and gives early career researchers (ie, graduate students, postdocs, and junior faculty) an opportunity to hone their writing skills.

Current Impact
From June 2023-May 2024, we had eight writers publish a total of 19 posts on MathStatBites. We currently have four authors signed on as continuing contributors and are in the process of recruiting more, with nine people showing interest so far.

In addition to our writers, we worked with graduate and undergraduate students to serve as editors and provide feedback as to whether we were communicating the research clearly for a student audience. Nine students participated as editors across the year.

Carry the Two Podcast

Concept
As part of IMSI’s goal to broaden participation and interest in mathematics and statistics, we are creating a podcast called ***Carry the Two***. Our basic premise is that each podcast

episode is a conversation between two hosts, with one leading the other through a discus sion of math research that shows how the field is interesting, applicable to our everyday lives. Each episode integrates excerpts from a separate conversation with an expert mathematician or statistician on that episode's topic. Through this podcast, we show that math is everywhere, relevant, and useful for navigating the complexities of everyday life.

Current Impact

Carry the Two is currently on its second season, having published eight episodes between June 6 and September 29, 2023. Each episode averages around 1400 downloads, with about 13,000 downloads overall.

The following guests and topics were featured in the nine episodes between June and September 2023:

- June 6: Angel Hsu (University of North Carolina, Chapel Hill) on climate change and urban heat island distribution as it correlates to neighborhood income.
- June 13: Dan Cooley (Colorado State University) on climate change, wildfire severity, and rare events.
- July 11: Kevin Grazier (NASA consultant, and science advisor for TV & film) on orbital dynamics and the sci fi hit from Apple TV, "Foundation."
- July 25: Robert Rossner (University of Chicago) and Paul Wilson (Uinversity of Wisconsin) on the history of nuclear fission at the University of Chicago and the blockbuster film, "Oppenheimer."
- August 8: Tara Kerin (UCLA) on epidemiology and HBO's "The Last of Us."
- August 22: Jamie Barty (Fuse FX) on the complex mathematics and physical modeling behind special effects in TV and film.
- September 5: Allyson Ettinger (University of Chicago) and Caitlin Parrish (playwright, television writer, and filmmaker) on the writers' strike against film and TV producers and the threat creatives face from artificial intelligence tools such as GPT-3.

Carry the Two went on hiatus in September 2023 due to change in personnel at IMSI. Subsequently, IMSI hired a new Director of Communications and Engagement and they are in the process of rebooting *Carry the Two* for in the Summer or Fall of 2024.

4. Preparation for Future Activity

The institute will host three long programs in 2024-25: The Architecture of Green Energy Systems (June 17-August 23, 2024), Statistical Methods and Mathematical Analysis for Quantum Information Science (September 16-December 13, 2024) and Uncertainty Quantification and AI for Complex Systems (March 3-May 23, 2024. The Scientific Committee recommended moving forward with these programs during its October 2022 meeting, at which point work with the organizing committees for both programs began. Potential participants were identified and invited to apply, workshop schedules were finalized, and workshop organizing committees were formed. Applications for all three programs opened in the fall, and were announced through a number of channels,

including advertisements in *SIAM News* and *Amstat News* and an announcement in the Mathematical Opportunities section of the *AMS Notices*. In addition, the spring 2025 program was announced through the Meetings Calendar of the Institute for Mathematical Statistics.

The IMSI Scientific Committee met in October 2023 and April 2024. The Committee recommended two proposals for long programs in 2025-26: Digital Twins: Mathematical and Statistical Foundations and Complex Applications in fall of 2025, and Reinforcement Learning in spring of 2026. In addition, the Committee recommended proceeding with the following workshop and school proposals:

- Mathematical Modeling of Biological Interfacial Phenomena
- Reduced-Order Modeling for Complex Engineering Problems (a 3-day school followed by a 5-day workshop)
- Emergent Behavior in Complex Systems of Interacting Agents
- Statistics Meets Tensors: Methodology, Theory, and Applications
- Statistical and Computational Challenges in Probabilistic Scientific Machine Learning (SciML)
- Mathematical Introduction to High-Accuracy Electronic Structure Theory (a 9-day school)
- Contemporary Challenges in Large-Scale Sequence Alignments and Phylogenies
- The Geometric Realization of AATRN (Applied Algebraic Topology Research Network)
- New Horizons on Model Transportability and Data Integration
- a reunion workshop for the fall 2023 program on Algebraic Statistics and Our Changing World
- a reunion workshop for the spring 2022 program on Mathematics, Statistics, and Innovation in Medical and Health Care
- sponsorship of the 15th International Conference on Monte Carlo Methods and Applications, to be held in 2025 at the Illinois Institute of Technology

5. Governance

IMSI has two principal governing boards.

The IMSI **Board of Advisors** provides guidance to the Director on Institute activities, operations, and strategic planning. In addition, it plays a role in the search for and appointment of the Director. The Board has dedicated seats for one institutional member from each of the partner institutions (Northwestern University, the University of Chicago, the University of Illinois at Chicago, and the University of Illinois at Urbana-Champaign), with the remaining seats allocated to general and *ex officio* members. Members serve four-year terms, except in the case of *ex officio* members. The current institutional and general members of the Board of Advisors are as follows.

Board of Advisors	Affiliation

Laura Appenzeller	University of Illinois Research Park and the University of Illinois at Urbana-Champaign
Chid Apte	IBM Thomas J. Watson Research Center
Noah Brenowitz	NVIDIA
C. Allen Butler	Daniel H. Wagner Associates, Inc.
T. Tony Cai	University of Pennsylvania
Adrian Coles	Bristol Myers Squibb
Juan de Pablo	University of Chicago and Argonne National Laboratory
Lee DeVille	University of Illinois at Urbana-Champaign
Darrell Duffie	Stanford University
Tamara G. Kolda	MathSci.ai
Pierre-Louis Lions	Collège de France
Steve Sain	Jupiter Intelligence
Brooke Shipley	University of Illinois at Chicago
Suzanne L. Weekes	Society for Industrial and Applied Mathematics (SIAM) and Worcester Polytechnic Institute
Karen Willcox	University of Texas at Austin
Patrick Wolfe (Chair)	Purdue University
Eric Zaslow	Northwestern University

The **Scientific Committee** provides guidance on the overall direction for scientific activity at the Institute and evaluates proposals for specific activities. Terms for members are typically three years in length. The current members of the Scientific Committee are as follows.

Scientific Committee	Affiliation
Alicia Carriquiry	Iowa State University
René Carmona	Princeton University
Andrew Childs	University of Maryland Institute for Advanced Computer Studies

Emil Constantinescu	Argonne National Laboratory and the University of Chicago
Peter Craigmile	Hunter College, CUNY
Amir Dembo	Stanford University
Sandrine Dudoit	University of California, Berkeley (UC Berkeley)
Bjorn Engquist (Chair)	University of Texas at Austin
Thomas Grandine	The Boeing Company (retired)
Jacqueline Hughes-Oliver	North Carolina State University
Claude Le Bris	École des Ponts and INRIA
Leslie Smith	University of Wisconsin-Madison
Joseph Tribbia	National Center for Atmospheric Research (NCAR)
Rebecca Willett	University of Chicago

6. Evaluation

IMSI works with East Main Evaluation and Consulting (EMEC) to evaluate its programs and activities. EMEC offers consulting and evaluation services with expertise in science and mathematics education and technology. The proposed effort will be managed by Barbara P. Heath, Ph.D. Dr. Heath founded EMEC in 2004 and has evaluated over 30 STEM focused programs including CyVerse (formerly iPlant), multiple Math and Science Partnerships, and various informal education efforts.

This year, post-activity surveys were deployed for the following programs and events:

Data Sciences Bootcamp
Career Paths in the Mathematical Sciences (mentor/student)
SUMSA
Laplacian Growth Models
Object oriented Data Analysis in Health Sciences
Young Scholars Program UIC
Young Scholars Program UC
Permutation and Causal Inference
IMSI Summer Internship Program
Invitation to Algebraic Statistics and Applications
Apprenticeship Week: Varieties from Statistics
Bring Math
Algebraic Statistics for Ecological and Biological Systems
Algebraic Economics

Bayesian Statistics and Statistical Learning
Algebraic Statistics and Our Changing World Long Program
Teaching and Evaluating Data Communication at Scale
Decision Making and Uncertainty
Computational Challenges and Optimization in Kinetic Plasma Physics
Methods for Solving and Analyzing Dynamic Models in the Face of Uncertainty and Cross-Sectional Heterogeneity
Materials Informatics: Tutorials and Hands-On
Machine Learning in Electronic-Structure Theory
Machine Learning Force Fields
Learning Collective Variables and Coarse Grained Models
Data Sciences for Mesoscale and Macroscale Materials Models
Data-Driven Materials Informatics

The surveys were designed to gauge the nature of participant experience during each activity, to measure the degree to which participants thought the specific goals for each activity were achieved, and to gather feedback about possible future directions. Surveys were typically deployed a few days after the end of the activity, and participants were given two weeks to respond. A reminder was typically sent a week after the initial deployment of each survey.

IMSI conducts surveys of participants in long programs two years after their conclusion to gather information about publications which were influenced by the program. This year, IMSI conducted surveys for two programs: the fall 2021 program on Distributed Solutions to Complex Societal Problems and the spring 2022 program on Decision Making and Uncertainty. These publications are listed in an appendix.

7. External Funding

IMSI receives substantial in-kind support from the University of Chicago. This support includes a full teaching release and administrative supplement for the Director, an administrative supplement for the Scientific Adviser, and the full salary of the Executive Director. In addition, the University covered the cost of the renovation of the space IMSI occupies and its ongoing maintenance.

The University of Illinois at Chicago provided support through a partial teaching release for the Associate Director.

Other Funding Support

University of Chicago Provost	$92,000.00
University of Chicago Physical Sciences Division Dean	$84,227.02
University of Chicago Macro Finance Research Program	$15,000.00
Total	$191,227.02

8. PI and Director Biographies

Kevin Corlette, Director and PI
Kevin Corlette was appointed as the Director of IMSI on August 1, 2020. He has been a faculty member of the Department of Mathematics at the University of Chicago since 1987. He served as chair of the department from 2001-2007, and again from 2017-2020. In addition, he served as director of the Master's Program in Financial Mathematics from 2012-2015. His research lies in differential and algebraic geometry, and has touched on areas such as non-Abelian Hodge theory, rigidity of lattices in Lie groups, and representations of fundamental groups of Kähler manifolds. He was a recipient of an NSF Postdoctoral Fellowship, a Sloan Research Fellowship, and a Presidential Young Investigator Award. He was an invited speaker at the 1994 International Congress of Mathematicians.

Dibyen Majumdar, Associate Director (January 1, 2023 to Present)

Dibyen Majumdar was appointed Associate Director of IMSI on January 1, 2023. He is Professor of Mathematics, Statistics, and Computer Science at the University of Illinois at Chicago, where he assumed the position of Assistant Professor in 1982. From 2009 to 2011 he was the Associate Dean of Research and Space of the College of Liberal Arts and Sciences, and from 2011 to 2022, the Executive Associate Dean of the College. Prior to that he was an Associate Head of Mathematics, Statistics, and Computer Science from 2004 to 2007, and the Director of the Statistical Consulting Lab from 1991 to 2005. He is a statistician whose main area of research is design of experiments, and it also includes the theory and methodology of linear and nonlinear models, and applications of statistics in biomedical research, especially design and analysis of clinical trials. His work on supersaturated design won the Shewell Award in 2013.

Takis Souganidis, Scientific Adviser

Takis Souganidis is Professor of Mathematics and Member of the Committee in Computational and Applied Mathematics at the University of Chicago. He works in deterministic and stochastic partial differential equations, and is interested in applied mathematics. He was a recipient of a Sloan Research Fellowship, and a Presidential Young Investigator Award. He was an invited speaker at the 1994 International Congress of Mathematicians and the 2019 International Congress on Industrial and Applied Mathematics. He is a Fellow of the AAAS, AMS, and SIAM.

Philip W. Hammer, Executive Director

Philip (Bo) W. Hammer was appointed Executive Director of IMSI on January 1, 2021. Hammer comes to IMSI after 10 years at the American Institute of Physics, where he was the founding and interim Executive Director of the AIP Foundation. He also led AIP’s major antiracism initiative that addressed underrepresentation of African Americans in physics

and astronomy. Hammer received his BS in Physics from Humboldt State University and his PhD in Physics from the University of Oregon. From 1991-93, Hammer was an ONR Postdoctoral Fellow at the Naval Surface Warfare Center in Silver Spring, MD. Hammer spent the '93-'94 year as an APS Congressional Science Fellow working on the staff of the Subcommittee on Science in the US House of Representatives. He worked at AIP from 1994-2000, and was Director of the Society of Physics Students and Sigma Pi Sigma. From 2000-2008, Hammer was a vice president of The Franklin Institute Science Museum in Philadelphia. Hammer is a Fellow of the American Physical Society.