The University of Tokyo

FoPM

Forefront Physics and Mathematics Program to Drive Transformation

Message from the Program Coordinator

University Professor,
Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU)

Hitoshi Murayama

Students with the skills to discover new knowledge can change the world

When you start a PhD, others often ask "why do you want to study so much?" But I think that your aim should rather be to find your own path and maximize your potential for the future benefit of humanity. Do you want to make breakthroughs in your academic field? Do you want to create a new business model? Do you want to change society by starting a new company, create a new future for Japan in government or politics, ensure the future of democracy by broadcasting correct and important facts in the media, or start out on a completely new journey in another country? Some of you may go back and forth between several of these different paths. Some of you may even change the fate of our planet with your expertise and critical thinking skills.

FoPM is designed to help you discover your own path of maximum potential by bringing students together from a variety of disciplines, including mathematics, physics, chemistry, engineering, astronomy, earth and planetary science, and neuroscience.

Be exposed to research and current issues in other subject areas in the 4PM Seminar and Lab Rotation. Study AI or quantum computing to develop basic skills that you can use whichever path you choose. Experience a whole new culture by doing research abroad. Open your eyes to new opportunities and learn networking skills in the International Career Seminar. Develop crucial communication skills that you didn't learn at school in Academic Writing and Presentation courses. Experience issues in industrial research and join workshops on entrepreneurship. Increase your awareness of the problems faced by humanity in courses on the SDGs and the Executive Program. Understand the issues surrounding diversity so that you can become a true leader and maximize the potential of those around you. FoPM offers you all this and more.

Coming back to the original question, "study" is to internalize what is already known. "Research" is to discover new knowledge that nobody in the world has known before. Once you can do this, you have the potential to literally change the world! I've been involved in training students in the US for almost 30 years, and one phrase that is used over and over is "You will make a difference." No matter which path you choose, make sure to discover a new stage for humanity.

The Power of FoPM

Discover the diversity and strength of FoPM

FoPM started out with the aim of training scientists to develop a broad perspective and the ability to make an impact in fields outside their area of expertise. That's why it offers such a diverse and powerful curriculum.

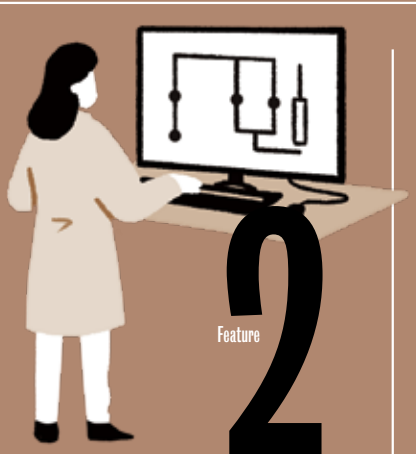
Feature 1

Integrated Master's–Doctoral program with financial support

FoPM is an integrated Master's–Doctoral program that trains "knowledge professionals", those with the ability to discover and apply new knowledge. In the hope that students will have the peace of mind to devote themselves to their research and studies during the five years of the program, FoPM provides financial support of ¥170,000 per month to Master's students and ¥180,000 per month to Doctoral students. This stipend is paid under the TAKUETSU Research Assistant (RA) scheme as remuneration for the research performed. Students set their own research goals and evaluate their own progress using the academic portfolio system. They are assessed in the Qualifying Examination (QE), which determines whether students may remain in the program as Doctoral students, and the Final Examination (FE), which marks their completion of the program.

Feature 2

AI and quantum computing as vital science skills



Reflecting the idea that AI and quantum computing are not only essential for cutting-edge science, but also a vital skillset for those who will lead the future of our planet, students are required to take courses in one or both of these subjects. In the Quantum Computing course, students have access to the state-of-the-art quantum computer IBMQ, and get hands-on experience in its use. The AI course gives students an overview of the basics of machine learning, data analysis, data mining, and other fundamental aspects of artificial intelligence.

Feature 3

Multiple encounters with other research fields

The regular 4PM Seminar is a place where FoPM students can interact freely beyond the boundaries of their laboratories. Each month, a diverse range of invited speakers give lectures on their research, then students give and evaluate each other's short presentations aimed at those working in other fields. In the Lab Rotation, students spend time in a second research group, which gives them the opportunity to acquire a broad perspective beyond their field of study. They also gain new perspectives through insights from their secondary supervisor, who specializes in a different area of research.

Feature 4

Research experience beyond national borders

FoPM supports the travel expenses for program students to experience academic research or a corporate internship overseas. Students are required to take part in this International Research Experience between the second year of the Master's program and the second year of the Doctoral program.

Feature 5

Science communication skills to promote research to the world

In the hands-on Academic Writing and Presentation course, students learn how to give effective presentations, as well as how to write and submit high-impact papers to major scientific journals. The instructors include Prof. Charles Yokoyama (IRCN), previously a senior scientific editor for the international journal Neuron; Prof. Mark Vagins (Kavli IPMU), who is well-versed in creating impressive presentations; and Dr. Kate Harris (Senior URA, School of Science), who has extensive experience in editing scientific writing. There is a separate course for mathematics students that focuses on the specific skills needed in this discipline.

Feature 6

Truly global leadership through Diversity and Ethics Training

FoPM's Diversity and Ethics Training aims to equip students with truly global values. It covers unconscious biases related to gender, sexual orientation, race, and more, as well as ways to overcome such biases and contribute to an inclusive society.

Feature 7

Enthusiasm to solve social issues with an entrepreneurial mindset

The Mathematics and Physics Entrepreneurship course supports students who want to make use of their expertise in basic science to take on the challenge of starting their own company. Guest entrepreneurs act as lecturers and students systematically learn how to set up a business from the very beginning. FoPM also actively promotes practical research with industry. The Frontiers of Mathematical Sciences and Society course shows students how mathematics can be used in industry and other disciplines, while the Mathematics in Society Hands-on course gives students the chance to go beyond the conventional applications of mathematics and apply their skills to solve problems presented by industry. Classes such as the SDGs Course and the Executive Program help students to gain an understanding of the issues faced by society today. This gives them the broad awareness needed to appreciate how their specialist knowledge of physics and mathematics can be applied to the benefit of the world.

Feature 8

Practical know-how for a future global career

The International Career Seminar demonstrates the importance of networking and sheds light on the multitude of potential career paths, whether in Japan or overseas. Invited speakers with experience of a wide variety of careers provoke students to think about their future from a variety of perspectives, while also providing advice in areas such as effective presentation methods, overseas networking, and finding a job in industry.

Proactive & Diverse

The Power of FoPM 01

Develop global communication skills and respect for diversity

FoPM provides students with the skills they need to become the "knowledge professionals" of the future. Knowledge professionals are able to communicate to the world beyond their field of expertise, and possess a broad perspective cultivated through experience of a diverse environment. Students learn the skills needed to write scientific papers and give effective presentations in English in the Academic Writing and Presentation course. The 4PM Seminar offers them a valuable opportunity to test these presentation skills and interact with leading researchers from Japan and abroad. The importance of respect for minority groups and a balanced awareness of gender is highlighted in the compulsory Diversity and Ethics Training, in which students learn that respectful interaction with people of different genders and backgrounds brings new perspectives and fosters researchers with true global sensitivity and values.

Keywords

1. Diversity and Ethics Training
2. 4PM Seminar
3. Empowerment of female students
4. Academic Writing and Presentation

1. FoPM's Diversity and Ethics Training develops students' abilities to interact with people with different viewpoints and provides a new approach to analyze opinions. Students also learn how to protect the rights of minority groups and make use of different perspectives. The instructor is Prof. Hiromi Yokoyama (Kavli IPMU), an expert in diversity education.

2. The 4PM Seminar is named after its starting time and is a play on words of the name of the program itself. Its purpose is to promote creative exchange among FoPM students, and world-renowned researchers are invited to speak each time.

3. FoPM operates a mentoring system in which each student is assigned a secondary supervisor, of which 13 are female faculty members. This system gives students a place to discuss any problems they may be having and provides particular encouragement to female and minority students.

4. In the Academic Writing and Presentation course, students learn about writing and publishing scientific papers in English and how to give presentations that will leave a lasting impression on their audience.

Turn the page for a discussion with FoPM students →

FoPM offers so many opportunities. It opens up a whole new world

Diversity and Ethics Training, Academic Writing and Presentation, Entrepreneurship, 4PM Seminars... FoPM offers all this and more. The program's unique features and curriculum provide students with a diverse range of opportunities and support. We ask four program students for their frank opinions on the benefits and appeal of FoPM.

Practical training for the science communicators of the future

——What did you think of the Diversity and Ethics Training?

Tanaka Diversity and Ethics Training is compulsory, so I went along because I had to, but it turned out to be more interesting than I'd imagined. I found it really compelling. We talked about how there are so few women in the sciences and learned that this is because society has created an atmosphere that is unwelcoming for them. I'd never thought about this before, and would have had no need to do so if I was only doing research, so it was a great opportunity. There was also a lecture on society's perceptions of science and technology, and through this I have become able to look at my research and myself as a scientist from another perspective.

Kawasaki It was new to me that there are academic fields dealing with gender equality and ethical research, and that we should address these issues as part of our scientific education. To be honest, before the seminar, I didn't think that this topic would be necessary for my research.

Sekine As a woman, I'm very grateful for this seminar. It just so happens that there are relatively many women in my laboratory, but I get the impression that there are many more men than women in the University of Tokyo as a whole. Women still face difficulties in certain situations. I hope that things gradually improve in these areas, and that everyone, including men, starts to learn more about the issues we face.

Hafid The lectures on diversity aim to eliminate discrimination and prejudice based on gender, race, and nationality, and I also found them very interesting. My specialty is mathematics, and the percentage of women in this field is low in Japan and throughout the world. These lectures made me think about the kind of efforts that might be needed going forward to increase the number of women working in mathematics.

—— What about the Academic Writing and Presentation course?

Tanaka The course includes practice in writing academic essays in English, and lectures on how to give good presentations. In one activity we swapped essays with other students and reviewed each other's work. I'd never done anything like that before. Previously, all I've had to do is scan other students' essays and give them a score. This course gave me the first opportunity to read and review someone else's work thoroughly, highlighting which parts were hard to understand and which were good. I was also able to see what was difficult to understand for someone from a different research field, so I think this is an excellent approach.

Sekine I felt that the lecturers were very conscious of the fact that we are the science communicators of the future. We learned in great detail about what to pay attention to when we publish a paper or explain something in public, and about the publication process. I've had plenty of lessons in English in the past, but this was the first time I'd taken a practical class in science communication, so it was very valuable.

Hafid The course was very impressive. We learned about the process of writing and publishing papers in English, what kind of journals there are, and about the peer review process. I think what we learned will be very useful when we attempt to publish our own papers.

Kawasaki How to write a paper and give a presentation are things that are traditionally passed down by word of mouth in each lab. I'd never really learned about them properly and only really had a vague understanding of the process. So, I think it's very meaningful that we were taught this in a systematic way. We were even shown Michael Jackson music videos as examples of how to capture an audience's attention (laughs).

First-year Master's Student, Department of Chemistry

Yuka Sekine

After graduating from Saitama Prefectural Urawa Girls' Upper Secondary School in 2017, Ms. Sekine entered the Department of Chemistry, Faculty of Science, at Ochanomizu University. Since 2021, she has been a member of the Ozawa Laboratory in the Department of Chemistry, Graduate School of Science, at the University of Tokyo.

First-year Doctoral Student, Department of Physics

Hiroaki Tanaka

After graduating from the Senior High School at Komaba, University of Tsukuba, in 2015, Mr. Tanaka entered the University of Tokyo's College of Arts and Sciences (Natural Sciences I). He graduated from the Department of Physics, Faculty of Science, in 2019 and joined the Kondo Group in the Department of Physics, Graduate School of Science. His specialty is condensed matter physics.

FoPM has given me a lot of valuable experiences

——How are the 4PM Seminars?

Tanaka I always look forward to the seminars as the organizers invite a variety of speakers who are well-known experts in their fields.

Kawasaki The seminars have been held online because of the pandemic, but it's not often that you get a chance to ask questions directly to a Nobel Laureate. I was very nervous, even though they were on the other side of the screen (laughs).

Sekine I thought it was really amazing too. We were able to listen to a talk online by Prof. May-Britt Moser, the Nobel Prize-winning researcher who discovered grid cells. The 4PM Seminars are currently held on Zoom, and after the student presentations we can talk with FoPM students from other years and departments in randomly assigned breakout rooms. I'm grateful to have these opportunities for discussion.

Discovering the links between science and society

——There are many other opportunities offered by FoPM, but which stand out for you?

Kawasaki There's a course called Entrepreneurship that was really interesting. I learned things that I wouldn't have had the chance to otherwise, such as the process of taking a startup from idea to goal. We presented our ideas to venture capitalists who actually invest in startups and asked them to decide how much they'd stump up. Unfortunately, my group scored a big fat zero yen for our presentation: they wouldn't invest in us at all (laughs). To be honest, I was never interested in starting a business, but after taking this course I started to think about the possibilities.

Sekine I'm taking the Frontiers of Mathematical Sciences and Society course. External speakers from companies or academia are invited to each class to talk about connecting mathematics with society or solving social issues using mathematics. I wouldn't have had so many opportunities to learn about the process of solving these issues using programming and mathematics if I hadn't enrolled in FoPM. My research is more towards the field of biology, so I'm really grateful for the opportunity to attend these lectures. I'm also taking a programming class called Introduction to Data Mining that is very informative.

Hafid In my case, one of the main reasons I joined FoPM was the Lab Rotation and secondary supervisor system. I thought it would be better to do more study and preparation before the Lab Rotation, so I'm planning to do it in the first year of the Doctoral program, but I'm already talking with my secondary supervisor. I'm studying mathematical analysis, but I wanted the chance to discuss my work with an expert in geometry because my research interests are related to both of these fields. So I chose a geometry professor as my secondary supervisor and he has introduced me to papers and other resources that have been very helpful.

Kawasaki My secondary supervisor is an authority on optical lattice clocks. We've had some real in-depth discussions on optics, and he's given me a lot of useful advice on experimental procedures. I'm grateful for the opportunity to learn from a famous professor, who I normally wouldn't even have the chance to speak to.

Tanaka I think it's great that we receive financial support from the first year of the Master's program. It's a privilege to be able to focus on our research without worrying about our finances.

Sekine I'm also very grateful for the financial support. My parents told me that I'd be on my own from my Master's degree onwards, so I'm relieved that I can do my research with the peace of mind that I receive enough support to be able to live by myself.

Kawasaki I think the greatest benefit of FoPM is that it provides so many opportunities. We have the chance to hear from people in various fields and careers, to learn about research being done in other fields by students our own age, and to take courses in entrepreneurship, AI, and quantum computing. I really think that FoPM helps us to broaden our horizons and opens doors to so many fields and possibilities.

First-year Master's Student, Department of Mathematical Sciences

Ayoub Hafid

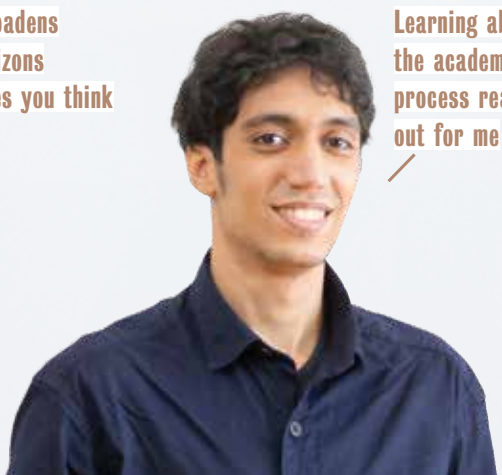
Born in Morocco, Mr. Hafid graduated from Elaraki High School in 2015. He was awarded a Japanese Government Scholarship from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and studied Japanese at the Japanese Language Center for International Students at Tokyo University of Foreign Studies in 2016, before entering the University of Tokyo's College of Arts and Sciences (Natural Sciences I) in 2017. In 2021, he graduated from the Department of Mathematics, Faculty of Science, and is now studying in the Kawahigashi Laboratory in the Department of Mathematical Sciences, Graduate School of Mathematical Sciences.

Second-year Master's Student, Department of Applied Physics

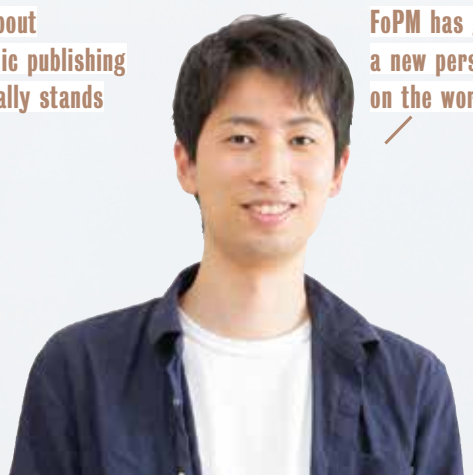
Akito Kawasaki

After graduating from Rakusei Senior High School in 2016, Mr. Kawasaki entered the University of Tokyo's College of Arts and Sciences (Natural Sciences I). Since 2020, he has been a member of the Furusawa Laboratory in the Department of Applied Physics, Graduate School of Engineering.

FoPM broadens your horizons and makes you think



Learning about the academic publishing process really stands out for me



FoPM has given me a new perspective on the world

Report #1

4PM Seminar

Everyone looks forward to 4 pm on Wednesdays

Held once a month on a Wednesday at 4 pm, the 4PM Seminar provides a place for FoPM students to meet and interact beyond the boundaries of their laboratories and talk with trail-blazing scientists from across the scientific world.

Invited researchers from various fields give lectures at the beginning of each seminar and program students have the opportunity to ask questions. The 4PM Seminar kicked off in February 2020, with Prof. Motoko Kotani of Tohoku University giving an interesting talk on the connection between contemporary mathematics and materials science, and has seen many renowned speakers participating since. In May and June 2021, Prof. May-Britt Moser, recipient of the Nobel Prize in Physiology or Medicine, and Dr. Fabiola Gianotti, Director of CERN, were invited to participate online.

After the lectures, FoPM students give short presentations on their research and evaluate each other's talks. In this way, they discover strengths and weaknesses of their own that they may not have noticed before and can thus develop their presentation skills.

The seminar ends with time for informal discussion. Participants are randomly divided into small groups and have the chance to talk with students and speakers working in different fields.

The 4PM Seminar is an intellectually stimulating event that only FoPM can provide, and every month students look forward to this special Wednesday afternoon.

1

2

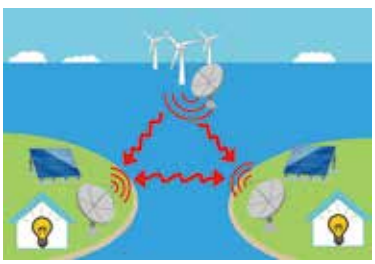
1 The 4PM Seminar has been held on Zoom during the pandemic.

2 A FoPM student asking Prof. May-Britt Moser a question online.

Essays #1

Unique essays by FoPM students

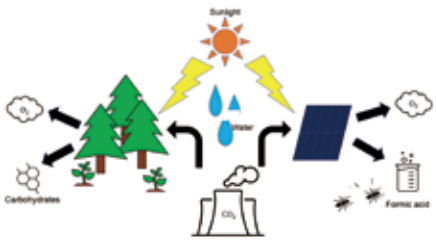
Some of the essays written by students in the FoPM Academic Writing and Presentation course



Solving energy problem with wireless transmission of electricity

Hiroki Fujimoto

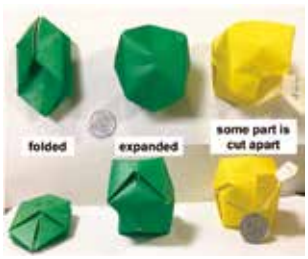
The author argues that the energy problem and climate change could be solved by wireless power transmission (WPT) using microwaves. By connecting the world through WPT and building an electrical power network, he believes that surplus renewable energy could be efficiently shared around the world.



Artificial photosynthesis toward better harmony with this planet

Hirokazu Kobayashi

The author focuses on the surprisingly efficient artificial photosynthesis device developed by the Toyota Group in 2021 as a means to address environmental issues. At the same time, he mentions the improvements needed for practical use of the device, and expresses hope that science and technology can help us live in greater harmony with the Earth.



Origami structures as a possible solution for privacy concerns in evacuation centers

Yuta Shiraishi

The author proposes a simple tent based on a Japanese origami balloon to protect the privacy and other human rights of people living in shelters in the event of disasters such as earthquakes and floods. The tent is easily set up by inflation with an air pump and can be folded compactly for storage. He also introduces other uses for such structures.

Beyond Borders

The Power of FoPM 02

Realize the dream of doing global research with FoPM

Every researcher dreams of working with outstanding scientists from around the world to enrich their research and discover the latest knowledge. If they can do it while still a student, so much the better. To train globally minded individuals, FoPM supports the travel expenses for students to carry out collaborative research at an overseas university or research institute, or to participate in a corporate research internship abroad. The International Career Seminar teaches students the importance of networking, essential for any future career, whether in Japan or abroad, in academia or elsewhere. Seminars have already been held on remote networking and online interviews, the need for which has become evident during the pandemic. Faculty members must also realize their role in helping students to achieve their dreams, and the program offers guidance on writing recommendation letters at the level expected by the international community.

Keywords

1. International Research Experience
2. International Career Seminar
3. Faculty Development

1. FoPM students are required to gain research experience at an overseas university, research institute, or company between the second year of the Master's program and the second year of the Doctoral program.

2. In the International Career Seminar, students learn essential skills for their future careers, including the importance of networking and how to deal with online interviews. Alumni and other professionals are also invited to introduce students to the diversity of career paths open to Doctoral graduates.

3. To maximize each student's career potential, faculty members must be able to write recommendation letters that can be trusted by external parties and conform to the international standard. A Faculty Development course will provide guidance on the expectations of the international community.

Turn the page for interviews with FoPM students →

I've always wanted to try new things and experience a different world

With support from FoPM making it possible to fulfil his dream of going out into the world to work with scientists from overseas, Mr. Eguchi talks about his International Research Experience at ETH Zurich in Switzerland.

——Mr. Eguchi, you've been doing research at ETH Zurich since October 2021. How have you settled in?

Every day, I go to the university to do research at around 9 am, and come home around 5 or 6 pm. When I get home, I sometimes continue working in my room. On my days off, I go to classical music concerts, which I love, or to the opera. There's a world-famous opera house here, the Zurich Opera House. As it happens, I've played the tuba for more than 10 years, and I used to belong to the University of Tokyo Orchestra.

——What kind of research are you doing?

I'm working on a large-scale particle physics experiment that's trying to clarify the origin of the universe by understanding the properties of neutrinos. This experiment is called T2K,[1] and is being conducted in Japan by as many as 500 researchers from around the world. ETH Zurich, where I'm based now, is also participating in the experiment, and I've been working with the researchers here to develop software for about two years now. We've been communicating online for a long time, but I've come here so that we can work more closely together on the research.

——What will the software be used for?

We're planning to replace the detector in the T2K experiment with a completely new one to achieve higher performance; that's scheduled to be installed next fall. The software we're developing will be used to analyze the data collected by the new detector. It will play a key role in enabling T2K to produce new experimental results ahead of the rest of the world. Neutrino research is said to be Japan's forte, and we have always been a world leader in this area. In the future too, Japan aims to stay at the top of the field through T2K and other experiments that seek to deepen our knowledge of neutrinos.

——Is being able to communicate in person much better for your research?

Yes. If I want to have a quick meeting, I can just turn to the colleague next to me and immediately get my message across. Whenever an idea comes to mind, we can discuss it here on the spot. That's a big advantage of in-person communication. I'm really glad I came here. My colleagues come from all over the world; they include Italians, Chinese, Spanish, Germans, and Americans, and I'm the only Japanese. I'm still struggling with English, but I'm managing to communicate well somehow.

——You're here for the FoPM International Research Experience. What are the best features of FoPM for you?

First, the financial support is a great help. And most of all, I think that it's really wonderful to be provided with all kinds of opportunities, such as this overseas exchange. I've always been keen to try new things, and FoPM's International Research Experience means I can do research with people from overseas instead of being restricted to Japan, something I've always wanted to do. There are many things in the world that we won't get to learn about if we just focus on research, so even after finishing graduate school, I'd like to continue looking for new experiences and challenging myself to do many different things.

There are people from all over the world and all sorts of backgrounds working together here

1. The T2K Experiment

A particle physics experiment in which the world's most intense neutrino beam, produced at the Japan Proton Accelerator Research Complex (J-PARC) in Tokai-mura, Ibaraki Prefecture, is directed towards Super-Kamiokande, located 295 km away in Kamioka. It aims to make precision measurements of neutrino oscillations. T2K (Tokai to Kamioka) began in April 2009 and is an international project with twelve participating countries, including Japan, the US, the UK, and France.

First-year Doctoral Student, Department of Physics

Aoi Eguchi

Graduated from Saganishi Senior High School in 2015 and entered the University of Tokyo. He joined the Aihara Laboratory in the Department of Physics, Graduate School of Science, in 2019, and the Yokoyama Laboratory in the same department in 2021. In the first year of his Doctoral studies, he spent time at ETH Zurich with support from FoPM.

Every day is rewarding in an environment where I can give my all to my research

Kept busy at the Paul Scherrer Institute in Switzerland with days in the lab and turns on night shifts, Ms. Matsushita talks about the appeal of FoPM and her dreams as a scientist.

First-year Master's Student, Department of Physics
Ayaka Matsushita

Graduated from Ferris Girls' Senior High School in 2016 and entered Waseda University in 2017. Since 2021, she has been studying in the Ootani Group in the Department of Physics, Graduate School of Science, and the International Center for Elementary Particle Physics at the University of Tokyo.

——Ms. Matsushita, you're currently working at the Paul Scherrer Institute in Switzerland. What's the topic of your research?

I'm working on the MEG II experiment here. MEG II is looking into the phenomenon in which elementary particles called muons decay into positrons while emitting gamma rays. If we detect this decay phenomenon, it will provide new leads for physics. My role involves detecting the gamma rays using a liquid xenon gamma-ray detector, and I'm aiming to improve the precision of the time resolution of the detector. I'm working at the Paul Scherrer Institute because the muon beam intensity produced by the accelerator here is very high. We are looking for decay phenomena that occur when we hit a target with a muon beam, so the stronger the beam, the better.

——Tell us about your daily life.

On weekdays, I work in the office or laboratory, running experiments and analyses. When we're using the muon beam for experiments, we work in shifts, taking turns to acquire data and monitor the system. We work 8-hour shifts, and the night shift is from 11 pm to 7 am, so I sleep during the day at those times. Don't worry, it's not like hard work or anything that'll ruin your health (laughs). I live in a guest house and I cook for myself. Typically, it's something with pasta or bread, nothing special. On Sundays, I usually stay in my room because everything is closed in Switzerland, but I enjoy photography, so on Saturdays I often go for walks and take photos.

——You've only been here for a month.

When I arrived, I was so happy to see the detector in real life. I'd only seen it in photographs before. There are still so many things I don't understand, but I'm learning how to use the equipment and how to collect data with the kind help of my colleagues. Soon we'll begin making measurements with the counters I made, something I'm really looking forward to. I'm still a bit worried about whether they'll work out ok.

——It sounds like it's going well.

Yes, compared with other particle physics experiments like the massive ATLAS experiment, MEG II is a medium-sized project, so even students like me can get involved in the fundamentals of the experiment. That's incredibly rewarding. I enjoy this environment a lot because it allows me to give one hundred percent to my research. This overseas exchange was actually paid for by my laboratory, but I'm sure that I wouldn't have had the opportunity if I hadn't joined FoPM.

——What are the best features of FoPM for you?

FoPM places great value on the connection between basic research and society. I'm planning to work in the private sector after obtaining my Doctorate, so I'm very interested in finding ways to return the knowledge and skills I gain in graduate school to society. It's also great to be able to interact with people from other fields. I have a long-standing interest in space development and exploration, so it was great fun to able to work in the Department of Earth and Planetary Science for my Lab Rotation.

——Would you like to go on an overseas exchange again?

Yes, once isn't enough. I'd like to do it several times (laughs).

Report #2

International Career Seminar

For students who dream of diverse careers

FoPM students set their sights on a diverse range of career paths. The International Career Seminar enables them to learn more about careers outside of academia and outside Japan.

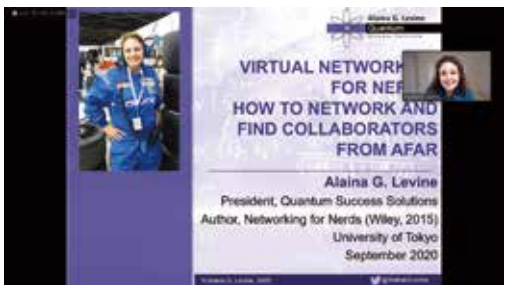
In 2020, we invited STEM career consultant and science journalist Alaina G. Levine to give a series of online workshops. Students discovered the importance of networking for their future career development and learned how to network and handle interviews in an online world. On the last day, students gave short presentations on their research and received professional advice on how to make them more effective.

In 2019, the seminar focused on postdoctoral research positions overseas. Researchers with experience working as postdocs abroad talked about the challenges they faced in a new environment, what they learned from the experience, and how to write effective applications.

The International Career Seminar was held again in 2021, with talks from alumni with careers both within and outside of academia. They talked frankly about their experiences, their thoughts as students, and why they chose their respective career paths. This opened students' eyes to the wide range of possibilities available to them after they graduate.

1

One of the talks at the 2019 International Career Seminar. The speaker is Dr. Hajime Fukuda, a Postdoc in theoretical particle physics at UC Berkeley.



2

The 2020 International Career Seminar was held with STEM Career Consultant Alaina G. Levine.

Essays #2

More unique essays by FoPM students

More essays written by students in the FoPM Academic Writing and Presentation course

Photo by Official SpaceX Photos – Starlink Mission (2021) CC BY-NC 2.0

Bridge the digital divide from the space

Fumihiro Naokawa

The digital divide is one of the inequalities of our time. Half of the people on the planet do not have access to the internet. As a solution to this divide, the author focuses on a constellation, or huge network, of 42,000 satellites. He introduces it with hope, without forgetting to point out its issues.

Mining Bacteria: A Solution for Shortage of Rare Metals

Masaya Sakakibara

The stable supply of rare metals has become a global issue. The author explains how, with the help of a group of microorganisms called mining bacteria, the energy costs and environmental impact of rare metal recycling can be reduced to an extremely low level. He also describes the chemical process and discusses its effectiveness.

Dream computer using quantum mechanics

Tatsuki Sonoyama

Quantum computers are expected to overcome the two major problems of the information age: high power consumption and limited information processing speeds. The author introduces the basics of quantum computers and examples of their application in drug discovery and logistics optimization. He also expresses hope that quantum computers will become a powerful new force in quantum mechanical research.

See the FoPM website for more essays by program students: https://www.s.u-tokyo.ac.jp/en/FoPM/activity/

AI & Quantum Computing

The Power of FoPM 03

Learn the common scientific knowledge of the next generation

Reflecting the idea that the next generation of researchers will need an understanding of AI and quantum computing, FoPM students are required to take courses in at least one of these subjects. Students can take advantage of the Japan–IBM Quantum Partnership formed by IBM and the University of Tokyo to get hands-on experience on IBM Quantum System One—the world's first gate-model commercial quantum computer—and the IBM Quantum-UTokyo Collaboration Center for collaborative research and study. Those who choose to take courses in AI will learn the basics of artificial intelligence, from the necessary programming skills to big data analysis techniques and neural networks. Studying the future of AI and quantum computing will boost each FoPM student's own future potential.

Keywords

1. IBM Quantum System One
2. Data analysis and programming

1. IBM Quantum System One is a state-of-the-art quantum computer equipped with a 27-qubit Falcon processor. It is installed at the Kawasaki Business Incubation Center in Kawasaki City, Kanagawa Prefecture, under an agreement signed by IBM, Kawasaki City, and the University of Tokyo. Following those in the US and Germany, this marks only the third installation of this type of quantum computer in the world.

2. Information processing skills have become indispensable owing to the rapid spread of AI and other new technologies. In FoPM's Introduction to Data Mining course, students learn about big data analysis and data mining by carrying out programming assignments. This experience provides students with the skills needed to contribute to the development of next-generation AI.

Turn the page for a discussion with the course organizers →

First-hand experience of pioneering challenges gives students the edge

FoPM students are required to take courses in AI or quantum computing, but just how important will these two subjects be for breaking through the scientific frontiers of the next generation?
We talk to course organizers, IBM's Dr. Rudy Raymond and the University of Tokyo's Prof. Hiroshi Imai, to find out.

Hands-on experience on an actual quantum computer

——What do you think has been achieved by making AI and quantum computing compulsory subjects in FoPM?

Raymond IBM made quantum computers available for use via the cloud for the first time in 2016. Then, three years ago, in 2019, Prof. Imai and I started an introductory course on quantum computing for FoPM, wondering what we could do for students using this cloud-based service. In 2021, the state-of-the-art quantum computer IBM Quantum System One was installed at IBM's facility in Kawasaki, Kanagawa Prefecture, for exclusive use in Japan. We plan to use it to further extend and enrich the content of our course and achieve even better outcomes next year.

Imai Also in 2021, a quantum computer test bed was installed at the Asano campus of the University of Tokyo under the Japan-IBM Quantum Partnership between the University of Tokyo and IBM, which was announced in 2019. I think it's really wonderful that anyone who is studying or doing research at the University of Tokyo now has access to an actual quantum computer. I'm delighted to see students being inspired by Dr. Raymond's fascination with a topic that will be so very important in the future.

Raymond The students are highly motivated and their group work in particular is excellent. They work in groups when they perform experiments with the computer, or when they try something new or something that couldn't be done before. For one major assignment, almost all the students made it to the final presentation, and some have even presented their work at international conferences.

Imai The University of Tokyo is home to some of the world's leading researchers in quantum computing, including the globally respected Prof. Yasunobu Nakamura of the Research Center for Advanced Science and Technology, who was the first in the world to build a superconducting quantum computer in 1999. With leaders such as Prof. Nakamura working in the field, we all agreed that it was vital to use actual devices to teach students about quantum computing at the University of Tokyo, and we have made that a reality.

Raymond In addition to Prof. Nakamura's major technological contributions, the University of Tokyo has also been at the center of pioneering theoretical research in quantum computing. So, from IBM's point of view, our partnership with the University of Tokyo is of great benefit. From an educational perspective, teaching programming is also vitally important. I'm therefore certain that the University of Tokyo will continue to be a key partner for IBM.

Imai We're still in the early stages of quantum computing. The future will surely bring us something new, something never seen before. However, the field is still in its infancy, and if we were to wait for quantum computers to reach maturity, we'd have to wait another 10 years. But unlike in the past—it took more than half a century for computers to reach their current level—the time it takes for a field to mature nowadays is accelerating rapidly. IT giants are also racing to invest heavily in quantum computing. In other words, the idea that we can just wait for 10 years until a fully complete product is available is no longer viable. It's important to get a head start now to win the race. I want our students to recognize this, and use the advantages that come with studying in the world-class environment at the University of Tokyo to make breakthroughs in research based on their own ideas.

The University of Tokyo is home to the world's leading researchers in quantum computing

Raymond There are already more than 200 quantum computing startups in operation worldwide, both in the software and hardware areas. The competition for talent is heating up across the globe. Now that devices with hundreds of qubits have been developed, I think that learning and research at the University of Tokyo will gain even more speed, for example, in drug discovery or solving the optimization problems in which Prof. Imai specializes. As a matter of fact, several students have emailed me to thank me and say that these lectures have inspired them to seek internships at companies involved in quantum computing. I'm glad that the students found the lectures rewarding. Several other students have asked if I could write letters of recommendation for them to study in the US. I believe that these lectures on quantum computing will be a powerful tool for students who are ready to take on the world. If you want to try something out on an actual quantum computer for your research, you usually have to pay for it and you also have to wait in line. It would be a great loss if such delays meant that you were unable to do high-impact research in time. But if you're a student at the University of Tokyo, you can immediately work on an actual state-of-the-art device, and your research can progress very quickly. I believe this is a great advantage.

FoPM creates a fusion of people and fields

—— What do you expect from FoPM and its students?

Imai Our graduate students are seeking to master science, and FoPM promotes an accurate and solid understanding of AI and quantum computing, the two future pillars of science. Of course, the students' main mission is to obtain a doctoral degree based on their own individual research problem. However, I think that knowing about AI and quantum computing —— that is, experiencing pioneering views and the challenge of creating new interdisciplinary fields with an eye to the future —— will give them the edge. In this respect, I take my hat off to the foresight of those who established FoPM.

Raymond We can also think of the application of quantum computing to AI, and vice versa: using AI to improve the performance of quantum computers. So there's no doubt that AI and quantum computing will be the two pillars of the next generation of science. In fact, major IT companies, including IBM, are convinced that's true. In that sense, I very much agree with FoPM's mission to give students an understanding of both AI and quantum computing.

Imai As a matter of fact, our FoPM lectures are very challenging. We've adopted the US style, with assignments and problem sets associated with each lecture. On weekends, we often get requests from students to extend the submission deadline a little (laughs). Quantum computing is a priority lecture and is assigned at least two teaching assistants. So, the students are receiving US-style lectures and we've invested in adequate classroom support. I think they're coping with it well. If I was taking the course, I think I might have failed (laughs). We're really strict on that.

Raymond Something that stands out is the number of women in the course. When I was a student, computer science was male-dominated, and probably only two in a hundred students were women. But women were much more prominent in this year's intake, and I'm glad that it's becoming more balanced now. Also, the main priority of this class is to make quantum computing accessible to students who are interested but would otherwise feel uncomfortable joining a class on the seemingly complex subject, so we cover a wide range of topics balancing theory and applications. What will they be interested in next? We want to be a gateway for students seeking to focus on the applications of AI or machine learning, as well as for those who want to move in the direction of hardware.

Imai Summing up, I think FoPM is a really interesting program that has something for everyone. I started research in quantum computing in the 1990s and was astonished at the number of excellent researchers I was able to network with at the University of Tokyo. Even though I'd just begun in the field of quantum computing, I got to know researchers in various other fields —— in physics, in electronics —— and came to realize just what a wonderful place the University of Tokyo is. FoPM students are in the enviable position of having that same experience now. It would please me no end if the students come to appreciate that the University of Tokyo is amazing by participating in FoPM. It truly is a program that creates a fusion of people and fields.

Professor, Department of Computer Science, Graduate School of Information Science and Technology

Hiroshi Imai

Graduated in 1981 from the Department of Mathematical Engineering and Information Physics in the Faculty of Engineering, the University of Tokyo, and obtained his PhD from the same university. After working as an Associate Professor at Kyushu University and the Faculty of Science at the University of Tokyo, he was appointed to his current position in 2001.

Researcher, IBM Research – Tokyo, IBM Japan; Part-time Lecturer, The University of Tokyo

Rudy Raymond Harry Putra

Graduated in 2001 from the Faculty of Engineering at Kyoto University and obtained his PhD in Informatics Engineering from the same university. He is engaged in research on algorithms, data analysis, and optimization at IBM Japan, and has contributed to numerous projects including big data analysis in industry. He has been teaching the FoPM "Introduction to Quantum Computation" course since 2019.

These lectures are a powerful tool for students ready to take on the world

Leading the Future

The Power of FoPM 04

Individuals who lead change and contribute to society: The vision of FoPM

FoPM set out with great expectations. Its global educational environment and efforts towards system reform are already evoking a strong response. We talk to four of the program organizers about what FoPM has achieved and what they expect from its future.

STEM talent, like stem cells, can become anything they choose

——Three years have passed since the inception of FoPM. What are your impressions of the program?

Hirachi When I took part in one of the 4PM Seminars, I noticed that the students were able to communicate effectively with those in unfamiliar fields. Mathematics students tend to be socially isolated (laughs), but I was delighted to see communication taking place across disciplines.

Murayama I have the same impression of the 4PM Seminars. The students' presentations are also excellent. Japanese presentation slides are typically packed full of text and difficult to read, but the students display their ideas simply on their slides, and are able to explain the rest orally. Another new initiative is the Diversity and Ethics Training. It is unbelievable from a Western perspective that gender-based gaffes could be made in a public forum, yet this still happens in Japan. If students don't understand this difference in sensitivity, they'll struggle abroad. For example, when you apply for a faculty position at a university in the US, you have to write a statement to describe how you plan to advance diversity. Therefore, Japanese students also need to have a basic knowledge of diversity and know how to behave appropriately. We have taken the first steps towards this end.

Harris When I first came to the University of Tokyo, I was surprised to see how few women there were here. When I studied chemistry in the UK, the numbers of women and men were roughly equal.

Murayama The International Career Seminar is another new feature of the program. I remember when I was a graduate student that my colleagues were always worrying about whether they'd be able to find an academic position in Japan. That path is unfortunately very narrow, but being unable to find a career that allows you to utilize your potential is a huge disappointment and a great waste of talent. That's why we wanted to create opportunities to show students that there are career options not only in Japan, but also abroad, in industry, in government agencies. Comments from the students show that they are starting to become aware of the diversity of career paths open to them, making it worth the effort, I believe. Also, making AI and quantum computing compulsory subjects is significant.

Hirachi I think studying AI and quantum computing will be a key advantage for students looking for work in industry. It's very important to understand the basics of these subjects. We're currently at a fascinating stage in the development of quantum computing. The English mathematician Alan Turing set the foundations for computers around the time of World War II, first developing the theory of what came to be called the Turing machine. This was before the emergence of transistor-based computers. Since he developed the theory first, it's true to say that the creation of computer software actually preceded that of computer hardware. Even further back, in the 19th century, another English mathematician, George Boole, laid the groundwork for logic circuits for digital computing encoded in only 0s and 1s. In other words, you can create something with basic science before the actual object that uses it is developed. I believe we are now in a similar situation with quantum computers. So this generation of students is very lucky, and if they continue in the field for the next 10 years, they could be at the top in no time.

Yamamoto In an era of rapid progress and constant change, it's the fundamentals that will ultimately win through. So, if you're working in quantum computing, you need to have a solid understanding of quantum mechanics, and if you're working in AI with only a superficial knowledge of numerical statistics, you're likely to stumble. FoPM has to keep AI and quantum computing in sight while providing a strong grounding in the fundamentals. If we do that, our students will become what I like to call STEM talent: just like stem cells, they can become anything they choose. After all, physics and mathematics are the basis of all scientific disciplines. I also think the challenge posed by the FoPM Lab Rotation is very important. Changing from a system that relies solely on a single academic supervisor to one in which multiple faculty members across several disciplines supervise students is key to broadening students' perspectives.

Harris I went to university in the UK, graduate school in Switzerland, and did post-doctoral research in Japan. I've also spent time studying in Germany. My impression of Japan from that experience is that Japanese researchers tend to confine themselves to their own research groups and don't interact much with colleagues from other groups. In Swiss universities, for example, major research equipment tends to be managed by the department and used by students, postdocs or faculty members from multiple groups. This creates an environment for spontaneous interdisciplinary exchange. In Japan however, such interdisciplinary

University Professor, Kavli IPMU

Hitoshi Murayama

Graduated in 1986 from the Department of Physics in the Faculty of Science, the University of Tokyo, and obtained his PhD from the same university. After working as a Research Assistant at Tohoku University and a Researcher at Lawrence Berkeley National Laboratory, he was appointed Professor at the Department of Physics, University of California, Berkeley (UC Berkeley). From 2007 to 2018, he was the founding Director of Kavli IPMU. Since then, he has held dual positions at the University of Tokyo and UC Berkeley.

Professor, Department of Mathematical Sciences, Graduate School of Mathematical Sciences

Kengo Hirachi

Graduated in 1987 from the Faculty of Science, Osaka University, and obtained his PhD from the same university. After working as a Lecturer at Osaka University and Associate Professor in the Graduate School of Mathematical Sciences, the University of Tokyo, he was appointed to his current position in 2010.

collaboration is rare. I think that is a key difference.

Murayama The students also find the Academic Writing and Presentation course taught by Dr. Harris and her colleagues to be beneficial. I've lived in the US for a long time and have noticed many issues with the Japanese education system when looking at it from the outside. One is that, although Japan produces excellent scientific research, researchers' ability to publicize their work is often found wanting. Good papers often fail to gain wider recognition, and when one does, it is often known as "the Japanese paper", rather than a specific individual's work. In other words, the author is invisible. It's a lost opportunity. Learning how to give persuasive presentations, write papers in English, and connect with others is key. Networking is still important in the scientific world: you start by reading the papers written by the people you know. We also asked an expert to talk about network building in our International Career Seminar.

Yamamoto As far as classes taught in English are concerned, the University of Tokyo already offers some, but I feel that the overall atmosphere of FoPM——the momentum I guess you could call it——inspires people to learn. Students aren't happy when they simply have to take more classes. But there's more to FoPM. That's the appeal of the program, don't you agree?

A future prime minister from FoPM?

——What challenges do you see ahead? What are your expectations for the future of FoPM?

Murayama The coronavirus pandemic has meant that we haven't really been able to send students abroad for the International Research Experience. Finding a way to provide this opportunity is the most important issue for us now. That, and guidance for faculty on how to write letters of recommendation for students. I'm planning to ask a Japanese researcher at the Max Planck Institute to give a seminar on that. Letters written by those without much experience outside the Japanese education system tend not to be very convincing in the international context, and can be a barrier to students maximizing their potential.

Yamamoto In a broad sense, the aim of FoPM is to reform graduate education in Japan. That includes changing the mindset of faculty members and reforming ingrained systems that have been built up over many years. FoPM offers a new perspective for a global standard of graduate education, and its practices are making a considerable impact. Our efforts are not confined only to FoPM, and I believe that expanding the Diversity and Ethics Training, 4PM Seminar, Academic Writing courses, and other initiatives will lead to significant reform. This won't be an easy task, but we've planted the seed and that is important. In the ongoing process of globalization, it is our dream to create an open system to accept truly excellent students from all over the world, and I believe that FoPM is making that dream a reality.

Murayama I totally agree with what Prof. Yamamoto said about people with a solid foundation in mathematics, physics, and chemistry being able to do anything, like stem cells. I think students with this kind of awareness will develop into people who are extremely motivated to take on new challenges. For example, Steven Chu, who was a colleague of mine at Berkeley, became Secretary of Energy in the Obama administration and also won the Nobel Prize in Physics. That's the kind of person setting the energy policy of the United States. The US businessman Elon Musk also noted that studying physics gave him the ability to think about things from a fundamental perspective. Former Chancellor of Germany Angela Merkel was also a physicist in her youth. It would be great to see a FoPM student become prime minister one day (laughs).

Hirachi At at Princeton, I worked with a young mathematician named Cédric Villani who won the Fields Medal. He is now a member of the National Assembly in France. People with a good grounding in basic science know how to get to the root of the problem and dislike contradictions. There are FoPM students who really understand mathematics working at the cutting edge of their discipline. It would be unfortunate if they all worked only in research and education. As Prof. Murayama says, I hope they will go on to be active in a wide variety of sectors.

Harris The University of Tokyo is aiming to become a university that anyone in the world would want to join. However, at the moment, I think many international students come to Japan because they are interested in anime or other aspects of Japanese culture. Few come for the science itself. I hope that FoPM will help boost the visibility of Japanese researchers, and that this will in turn lead to more young people from around the world thinking "I want to work with that professor at the University of Tokyo", and coming to Japan for that reason.

Hirachi It's true that the University of Tokyo is not yet attracting the best students from abroad. However, FoPM's approach is already the global standard, so if we sustain our momentum, the top international students will start to apply to the University of Tokyo along with Harvard, Princeton, and Berkeley. I think that will be a great stimulus. But to achieve that goal, we'll need to reform the mindset of the faculty as well.

Murayama Yes. You're absolutely right.

Professor, Department of Physics, Graduate School of Science

Satoshi Yamamoto

Graduated in 1980 from the Department of Chemistry in the Faculty of Science, the University of Tokyo, and obtained his PhD from the same university. After working as a Research Assistant at Nagoya University and Associate Professor in the Graduate School of Science, the University of Tokyo, he was appointed to his current position in 2004.

Senior URA, Office of Research Strategy and Development, Graduate School of Science, Part-time Lecturer, The University of Tokyo

Kate Harris

Graduated from the University of Edinburgh in 2005 and obtained her PhD in chemistry from the University of Basel in 2010. She moved to Japan as a Postdoctoral Researcher at the Graduate School of Engineering, the University of Tokyo, and has since worked as a Senior Editor of academic papers and other publications. She was appointed to her current position, in which she provides support for the organization and management of FoPM, in 2017.

Message from the Program Director

Dean, School of Science, The University of Tokyo

Masahiro Hoshino

Graduates will advance social innovation through challenging, interdisciplinary research

Selected for support by MEXT's Doctoral Program for World-leading Innovative & Smart Education (WISE Program), FoPM leverages the strengths of the world-class research environment at the University of Tokyo's School of Science and Kavli Institute for the Physics and Mathematics of the Universe. It is an integrated Master's-Doctoral program with a curriculum that spans disciplines and national boundaries, demonstrated by the participation of three companies and numerous overseas universities and research institutes, including UC Berkeley, Caltech, and Harvard. The program aims to maximize each student's individual potential and train Doctoral graduates with the research skills and expertise needed to make a significant contribution to society. It also provides an environment that allows exceptional students to concentrate exclusively on their research, with initiatives including a selection process in which financial support is secured before students confirm their place.

As one of the university-wide World-leading Innovative Graduate Study (WINGS) Programs, FoPM pilots new initiatives in interdisciplinary education and provides training in areas such as diversity, ethics, and academic writing. For example, students acquire a broad perspective of science through the Lab Rotation, in which they gain experience in a completely different field to their chosen discipline. The 4PM Seminar features presentations by internationally active researchers, including Prof. May-Britt Moser, recipient of the Nobel Prize in Physiology or Medicine in 2014, and Dr. Fabiola Gianotti, Director General of the European Organization for Nuclear Research (CERN), and provides a venue for casual discussion among FoPM students with an emphasis on breaking down barriers between disciplines. The International Career Seminar helps students to form a vision for their future by providing opportunities for them to interact directly with international faculty and those with research experience overseas, STEM career consultants, and researchers from industry. It also gives them the chance to acquire the self-promotion skills needed for their future international careers.

Students in pursuit of the fundamental principles of mathematics and physics from the Graduate School of Science, the Graduate School of Mathematical Sciences, and the Graduate School of Engineering participate in FoPM. These students seek to take on the challenge of interdisciplinary research that transcends existing frameworks and succeed in the quest to advance social innovation. We anticipate that they will become future world leaders in academia, industry, and many other areas of endeavor.

東京大学
THE UNIVERSITY OF TOKYO

FoPM