Connect

WITH THE INDIAN INSTITUTE OF SCIENCE

Volume 5 | Issue 1 | February 2018

Talent Development Centre
An IISc teacher training initiative

Roorkee or Bangalore?
How IISc found its home

Test tube trees
Looking back at biotech innovations

ISSN 2454-6232

IN THIS ISSUE

EDITORIAL

IISc was established in 1909, preceded by several conversations about the need for such an Institute, what its purpose should be, and how to achieve that purpose. It's a conversation that has been revisited multiple times in the last century and more, and in some ways has broadened considerably, expanding to questions about how learning can be achieved beyond the confines of a degree, and who a learner is.

From our archives, we bring you some of the conversations that happened before the Institute was set up in a delightful exploration of how Bangalore came to be its home. We also look at the impact that World War II (which lasted from 1939 to 1945) had on the Institute, and how it pushed research at IISc down new avenues. And don't miss the excerpt from the autobiography of Robert Travers about his father Morris Travers, IISc's first Director, who quarreled with JN Tata's sons over the direction the Institute should take, and left India bitter about the experience.

This issue of *Connect* focuses on the Institute's various attempts to spread learning to a wider audience, supporting outreach programmes for students, teachers, and individuals of all ages. There's the Talent Development Centre (TDC) at IISc's Challakere campus, where around 1500 teachers from all over the country are trained every year; the Centre for Continuing Education that offers students, college teachers and professionals everything from evening language classes to courses on deep learning; the science education initiative for young students at Bangalore's Jawaharlal Nehru Planetarium that IISc faculty contribute to, and the Indian Nanoelectronics Users' Program (INUP) for students and faculty to build national capability in nanoelectronics.

IISc is also involved in research and innovations that have a broader societal impact. We offer you a glimpse behind the Climate Change Calculator and other efforts at the Divecha Centre for Climate Change; the numerous inventions by the Centre for Sustainable Technologies, and the very latest PEDL cycle-sharing system on campus being used as a pilot programme for sustainable transport options.

This issue, you'll also get to meet retired biotech pioneer Lakshmi Sita, biotech entrepreneur Fathima Benazir, and the fluid dynamicist Garry Brown.

Published by the Archives and Publications Cell (APC) at the Indian Institute of Science (IISc), *Connect* is a quarterly magazine that seeks to bring together the IISc community and engage with the outside world – through stories about life in the Institute, its research, and rich heritage.

TEAM CONNECT

Deepika S
Karthik Ramaswamy
Kaushal Verma
Manu Rajan
Megha Prakash
Nithyanand Rao
Rohini Krishnamurthy

CONTACT

Email: connect@apc.iisc.ernet.in

Phone: 91-080- 2293 2066

Address: Archives and Publications Cell,
Indian Institute of Science,
Bangalore 560 012

http://connect.iisc.ac.in

Design: Magnetyz | **Printer:** Sri Sudhindra Offset Process

Improving the quality of India's teachers

Rohini Krishnamurthy

The Talent Development Centre at the Challakere campus trains around 1500 teachers at the high school, pre-university, undergraduate and postgraduate level every year

According to the Annual Status of Education Report (ASER) 2017, a survey that assesses the quality of learning among students in rural areas, only 43 percent of children aged between 14 and 18 can perform simple arithmetic operations like dividing a three-digit number by a one-digit number.

These startling results are despite the government's initiative to make education a fundamental right for all children aged between six and 14. Student enrollment, which has been above 96 percent since 2009 – as recorded by ASER – has done little to address the issue. The reason behind this poor show can perhaps be attributed to a dearth of well-trained teachers employed in schools.

To improve the standard of teaching in India, from 2011, the government began screening aspiring teachers through the Teacher Eligibility Test (TET). Unfortunately, this has been undermined by the fact that aspirants have performed poorly. For example, in 2016, the TET conducted in Karnataka saw only 20 percent of the aspirants clearing the test. As a quick fix, several states have exempted aspirants from taking the TET, making the situation deplorable: a small section of students schooled by these teachers with inadequate knowledge, may go on to train the next inflow of students, creating a vicious circle. Other measures to strengthen the quality of teaching in the country are necessary.

IISc, for its part, has been actively involved in several outreach activities created to improve the quality of teaching at schools and colleges for 30-odd years, and has now developed a permanent training programme for teachers.

In 2011, the TDC was inaugurated, and trained its first batch of over 100 high school teachers in science and mathematics from Chitradurga district

How it all began

In 2009, when IISc was celebrating its centenary year, P Balaram, the Director at the time, announced the establishment of a second campus at Challakere in Chitradurga district, Karnataka. After a visit to one of the teachers' training sessions being held at IISc, he saw the need for a permanent facility, and began contemplating developing a centre for teacher training at Challakere. That spurred the formation of the Talent Development Centre (TDC) on the second campus, according to MS Hegde, CSIR Emeritus Scientist and Convenor of the TDC.

In 2011, the TDC was inaugurated, and trained its first batch of over 100 high school teachers in science and mathematics from Chitradurga district.

The transformed sheep breeding farm

Several IISc faculty and staff were working behind the scenes – overseeing the renovation activities, designing curriculum for the 10-day intensive training, and setting up equipment for the laboratory

Setting up of the TDC wasn't a cakewalk. The building that houses the Centre once used to be part of an abandoned and decrepit sheep breeding farm. The Institute acquired the property on lease from the government of Karnataka. Revamping the dilapidated property began in full swing soon after that: from designing laboratories to classrooms, a dining hall and kitchen. With the supply of electricity, water, and internet, the Centre was ready to function. Several IISc faculty and staff were working behind the scenes – overseeing the renovation activities, designing curriculum for the 10-day intensive training, and setting up equipment for the laboratory. The Karnataka government supported the Institute by providing 32 residential quarters that can accommodate 125 trainees.

Photo: TDC

Residential building for the trainees

The journey so far…

A day in the life of the trainees at the TDC includes morning classes followed by experiments centred on the topics dealt with earlier. High school teachers perform over 90 experiments, spending more than 10 hours each day during their 10-day stay. Understanding science, according to Hegde, involves backing theory up with experiments. The training is aimed at arming teachers with the knowledge required to teach students in the best possible manner.

The benefits of this programme can be realised by assessing the knowledge of the teacher trainees before and after the training

Photo: TDC

Photo: TDC

Chemistry laboratory (left) and a theory session (right)

Training in the mathematics stream involves engaging the trainees in assignments in the classroom itself, followed by classroom lectures, says Hegde.

The benefits of this programme can be realised by assessing the knowledge of the teacher trainees before and after the training. In June 2016, for example, teachers from Haveri scored an average of 18.8 on 100 in a test prior to the training. After training, the average marks escalated to 84. Elaborating on the impact of the training, Hegde says, "Out of 1,122 teachers trained in 2016-2017, only seven have scored below 35 percent." Moreover, the manner in which the trainees are graded is stringent. "They have to answer more to score a single mark and we don't award marks in part. It's either whole [numbers] or zero," Hegde adds.

A trainee from Raichur district, Hemavati, says she finds the training well-planned and useful. "As this [programme] is mainly practically oriented, we don't miss out anything important," she adds.

Apart from high school teachers, this programme is extended to training pre-university, undergraduate and postgraduate teachers. Some of the equipment in the laboratory, such as an apparatus to measure thermal expansion, was built from scratch by Hegde and team.

The Centre is also focussed on creating a hotbed for research. To help postgraduate teachers, Raghavendra, a Research Associate who also teaches at the Centre, is standardising facilities for experiments on cloning, which allows production of microorganisms that are genetically identical. Several PhD students from IISc are also working at the Centre.

Despite their efforts, there is one cause for concern: the lack of facilities for trainees who are accompanied by their toddlers. The current batch, for instance, saw around five female participants attend with their children and they had to juggle the training programme with tending to their kids. "They show immense dedication and interest," says Hegde with a smile.

Recognition

Hegde points out that in the seventh year of the programme he met the Additional Chief Secretary for Primary and Secondary Education in Karnataka, Ajay Seth. Looking at the performance reports, Hegde describes Seth as being "stunned". The Centre evaluated the inspectors of subjects appointed by the government to train high school teachers every year: they scored less than the regular teachers did. Acting on this, Seth issued orders to all the Deputy Directors of Public Instruction in Karnataka that they each send 120 teachers to the TDC for training. And from then on, government officials have been keen on this programme.

This programme received a further boost in February 2015, when Prime Minister Narendra Modi visited IISc. He was shown a presentation on the progress of IISc: two slides on TDC caught his attention and he expressed interest in the programme. This is how the government decided to include TDC under the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching, a scheme aimed at boosting teacher training in the country. IISc is the first centre under this mission.

Apart from the Department of Science and Technology and the Karnataka government, TDC has also received funding from the Ministry of Human Resource Development, beginning March 2015.

Photo: TDC

The proposed building on the new campus

What is in store for TDC?

The current facility is a temporary one. By March 2019, it will shift to the new 1,500-acre campus which is not far from the current campus. Construction of a training centre with large classrooms, an auditorium, and a cafeteria is underway. Hostels that are coming up can accommodate 200 teachers at a given time.

In addition to TDC, the facility in Challakere is also creating a Skill Development Centre in association with Hindustan Aeronautics Limited: people will be trained in various engineering disciplines so as to benefit the manufacturing sector. The facility is expected to begin functioning by March 2019.

It is imperative to hire trainers on a permanent basis, without which the future of the TDC cannot be imagined, says Hegde

But development could have its accompanying ill effects. Far from human inhabitation, the flora and fauna at IISc's second campus was surveyed by a team from the Centre for Ecological Sciences. This survey revealed that the campus is home to the blackbuck, Indian fox, black-naped hare and several birds. BN Raghunandan, Chairman, TDC says, "Twenty-five percent of the land will be untouched based on [the] master-plan [that was] proposed."

Talking about the challenges the TDC is facing, Hegde rues, "Currently trainers are employed on a contract basis." It is imperative to hire trainers on a permanent basis, without which the future of the TDC cannot be imagined, he says. He suggests that the Institute hire, as teacher trainers, assistant professors, associate professors and professors from the physics, chemistry, mathematics and biology streams. Underlining the need to have faculty who can actively carry out research, Hegde adds, "Teaching requires innovation and the way to innovation is through research. Trainers without research experience might not be good at the job."

The TDC has had a successful run so far, and the performance reports of trainees indicate a positive impact. Currently, there are no provisions to measure the long-term impact of the programme. As for future plans, Hegde adds, "We are training about 1500-1600 teachers each year. The aim is to increase this number to 2800," he says.

REAPing for the stars

Ranjini Raghunath

A science education initiative at the planetarium, which IISc faculty members contribute to, strives to turn more local students into scientists

Photo: Ranjini Raghunath

Narmada Khare teaching Bio-REAP students

On a sunny Saturday afternoon, as hundreds of chattering kids throng the Jawaharlal Nehru Planetarium to gaze at the stars, a small group of college students makes their way down to the planetarium's basement lecture hall where Narmada Khare is teaching a class on "the molecules that make life". Khare, an undergraduate biology instructor at IISc, has been spending the previous few Saturdays introducing them to the basics of genetics. "They mentioned that they wanted to learn more about development next, so today, I am beginning with biomolecules," she says.

Khare's classes are part of the planetarium's popular Research Education Advancement Programme (REAP), a two-year weekend programme aimed at encouraging local undergraduate students to develop a passion for pursuing research. Organized by the Bangalore Association for Science Education (BASE), it is geared not just towards making them understand scientific concepts better, but also to train them to think like a researcher.

REAP is a two-year weekend programme aimed at encouraging local undergraduate students to develop a passion for pursuing research

"I try to tell them about the scientists, how these ideas evolved, the stories behind the discoveries," says Khare. "A few times, I ask them, if this was the question, how would they go about solving it? Or, if this was the observation, what would the question be?"

Students who sign up for the programme spend a couple of hours each weekend learning from and interacting with practising scientists, who explain fundamental scientific concepts in a more informal and interactive setting than their college classrooms. Courses in biology and physics are organized separately (REAP in Physical Sciences, and "Bio-REAP"). Students in the physics programme also have the opportunity to pursue a research project after two years.

Over the last two decades, the programme has roped in dozens of leading scientists from across Bangalore to volunteer their time over the weekend teaching the students. In addition to faculty members at RRI, IIA and ICTS, many physics faculty members from IISc have been involved with the programme for several years. Faculty members from the Division of Biological Sciences also played a key role in setting up the Bio-REAP initiative, and continue to coordinate the programme.

Nurturing local talent

In the early '90s, noted physicist Bala Iyer, then at RRI, used to spend his evenings and weekends at the planetarium explaining physics concepts to a handful of enthusiastic undergraduate students. He was later joined by particle physicist S Lokanathan, currently retired from the University of Rajasthan.

"Both Prof Iyer and Prof Lokanathan were committed to the cause of science education," says Madhusudan HR, senior scientific officer at BASE. Working with the late founder-director of the planetarium, CV Vishveshwara, they identified core concepts that are important for a career in research and began teaching regular weekend classes, gradually giving shape to a formal programme in 2000.

REAP classes typically begin at the start of the academic year, and attendees are mostly undergraduate students from in and around Bangalore. With growing popularity, the programme has also been getting students from places such as Shimoga, Tumkur, Kolar and Bagalkot in recent years, says Madhusudan.

Several IISc faculty members from the Department of Physics and Centre for High Energy Physics (CHEP) have been teaching there since its inception.

"I used to teach quite regularly from 1995 till about 2010," says Rohini Godbole, Professor, CHEP, whose classes usually focused on developments in theoretical physics. "The students one talked to were very enthusiastic and truly interested in science."

The programme is tailored for first year and second year BSc students, but attendees come from a variety of backgrounds, says V Venkataraman, Chair, Department of Physics, IISc. "Right now, in my class, there are students from second year BSc, first year MSc, and from engineering," he says. "The common thread is that they are coming voluntarily. That makes them more interested in what we are talking about and makes them want to learn more."

As the physics programme grew in popularity, around 2006, BASE decided to organize a similar initiative for biology. At that time, S Mahadevan, Professor at the Department of Molecular Reproduction, Development and Genetics, IISc, was already volunteering for weekend study sessions, and offered to help set it up. A committee was then formed including several faculty members from IISc, and an initial three-year

programme titled "Bio-REAP" was formulated, which later changed to a two-year programme.

"The idea was to nurture local talent. Students from Bangalore were not getting into science and into major scientific institutions including IISc," says Dipankar Nandi, Professor at the Department of Biochemistry, IISc, who was the Bio-REAP coordinator until recently. "The effort was part of giving back to the city."

Faculty members from the Division of Biological Sciences played a key role in setting up the Bio-REAP initiative, and continue to coordinate the programme

The programme is typically broken up into several four- to five-week course modules spread over two years. It usually starts with ecological sciences, moves on to basic sciences such as cell biology and biochemistry, and ends with translational areas such as immunology and neurobiology.

Most of the current Bio-REAP instructors are IISc faculty members. However, faculty from other institutes too, such as Anindya Sinha of the National Institute of Advanced Studies, Sanjay Sane of the National Centre for Biological Sciences, and KN Ganeshaiah and several others from the University of Agricultural Sciences have been teaching at the programme for several years. Many students who attended Bio-REAP over the years have spent their summers in IISc labs. Some of them have completed their PhDs from the Institute. Graduate students from IISc have also taught a few classes at Bio-REAP.

"Not a tutorial centre"

At its core, the programme seeks to inculcate a deeper understanding and appreciation of science, and not merely coach students to clear PhD entrance exams, according to Madhusudan. There are no screening tests for applicants, and students sign up for the programme purely out of interest. About 120-130 students sign up for the classes initially, but by the fifth or sixth class, the number trickles down to about 35-40, he points out. "We make it very clear to them that this is not a tutorial centre."

The informal setting also gives students the opportunity to study science without the pressure of exams or deadlines, delve deeper into concepts within their curriculum, and also learn more about topics not in their syllabus. "It was much more rigorous than the college level exposition that we would get," recalls Vijaykumar Krishnamurthy, faculty member at ICTS, who attended REAP classes when he was pursuing BSc at MES College, Bangalore. Bala Iyer, for example, would pick up a textbook from the US undergraduate curriculum and solve those problems, he says. "Because it was taught by active scientists, it made a huge difference hearing about something from someone who actually uses it in their daily work."

Apart from interactions with leading scientists and connections with scientific institutions, students also get to learn more about the various career options available to them after graduation, says MRN Murthy, Professor at the Molecular Biophysics Unit, IISc, the current Bio-REAP coordinator.

"I was interested in research since 10th standard, but I didn't know where to go, what to do. I don't come from a family with a scientific background," says Krishnamurthy. "The connections that opened up to various scientific institutes really made a difference." He went on to pursue his PhD at IISc under Sriram Ramaswamy, complete postdoctoral stints at Yale University and the Max-Planck Institute, and then take up a faculty position at ICTS, Bangalore. He has also been teaching at REAP for the last three years.

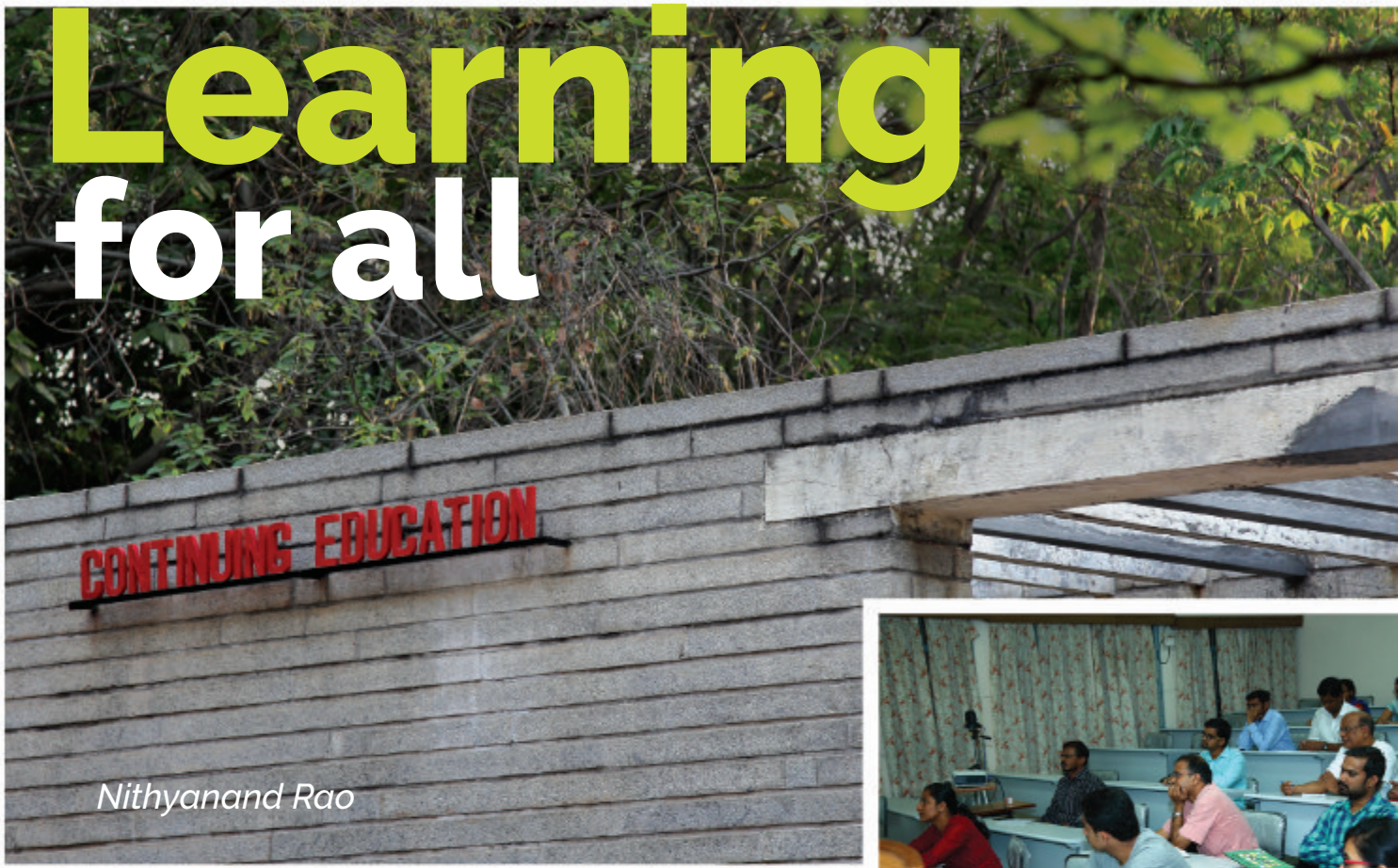
Ranjani Vishwanatha, another REAP graduate, credits the programme's approach to honing the students' thinking process for her successful admission into IISc's Integrated PhD programme.

"It definitely trained us to see how we should attempt the interviews, what we should look for, how should we start thinking about research or solve problems in general," she says. "Even though the training was in physics, it helped me attend chemistry interviews and exams. I don't think I would have directly qualified without this kind of 'thinking process' training." Vishwanatha did her Integrated PhD under DD Sarma, Professor at the Solid State and Structural Chemistry Unit, IISc, and is currently a faculty member at JNCASR. She has also returned to teach at REAP.

Like Krishnamurthy and Vishwanatha, about 100 "REAPers" have gone on to pursue successful research careers in India and abroad since its inception, says Madhusudan.

"When I joined IISc, I was the only integrated PhD student from Bangalore in the ten years that the programme had been running," says Vishwanatha. "Now I can see that every year, there are at least a few people coming in to Bangalore institutes for PhD and Integrated PhD programmes from REAP."

Learning for all



Nithyanand Rao

Photos: CCE

The Centre for Continuing Education has something for everyone

The Centre for Continuing Education (CCE) grew out of an awareness that, for institutions like IISc, imparting knowledge to people beyond their boundaries is an important part of their service to the community. Continuing education, as a brochure from CCE's early years states, is the idea that the education of professionals, because of the rapid strides in science and technology, should be "continued in short spans of time over their entire career rather than be confined to a single extensive stretch", and that this can be achieved with "a complete integration of education with work during their productive lifespan".

Aiming to meet the continuing education needs of R&D labs, industries and college teachers, CCE was set up in 1975. "We have different programmes for these different target groups, and each programme has a faculty member of the Institute as the coordinator," says GL Sivakumar Babu (Professor, Department of Civil Engineering), Chair of CCE.

One of the oldest such programmes is the Quality Improvement Programme (QIP), begun in 1970 nationally, and in 1972-73 in IISc (later brought under the purview of CCE). It aims to "upgrade the expertise and capabilities" of teachers at engineering colleges that are accredited by the All India Council for Technical Education (AICTE), by enabling them to pursue MTech and PhD programmes at QIP centres. IISc is one of the nine major QIP centres, having awarded 227 PhD and 236 MTech degrees under this programme since 1980.

But there's not much demand for MTech admissions through QIP now, says G Narayanan (Professor, Department of Electrical Engineering), the coordinator for QIP, because most teachers at engineering colleges these days already have an

MTech. From the small number who apply, only one has been selected in each of the last three years. For the PhD programme too, the number of selections have come down in recent years because of a dearth of quality applicants, as well as the fact that many applicants choose to go to other, smaller, QIP centres which are perceived to have a less rigorous academic environment. Only four PhD applicants were admitted in each of the last two academic years under QIP, with 15 currently on roll.

The PhD students who enter through QIP stay on campus for three years, and are then expected to go back to their colleges and continue their research work. But this proves difficult for most people due to the teaching workload at their colleges, says Narayanan.

There are also week-long courses for college teachers organised under QIP, sponsored by AICTE. Around 20 such courses have been organised in each of the last two years, an increase from the handful that used to be conducted earlier. These courses benefit hundreds of teachers from engineering colleges. "Teachers are force-multipliers, because good teachers can then make a difference to hundreds of students they teach," says Narayanan, who has taught QIP short-term courses. "If you're able to connect with them, their response is good. Some of them have written very moving and touching comments in their feedback."

Proficience is a unique programme that offers courses open to anyone with the prerequisites. These are semester-long courses on varied subjects – from French language courses to ones on deep learning – held for two or three hours a week during evening hours so that working professionals can attend after their office hours. These courses are at the postgraduate level – mostly taught by IISc faculty but some from outside IISc too – and are often courses that are offered to IISc students. Around 50 such courses were offered last year, benefiting working professionals who need to acquire new knowledge.

"It's not just the papers from IISc that should go out," says Narayanan of these courses. "The body of knowledge that is present with the faculty of the Institute should be available to society and should benefit the practitioners who could use such knowledge."

The Proficience programme – whose coordinator is P Balachandra (Principal Research Scientist, Department of Management Studies) – was started in 1980, when it was practical for people to commute to attend evening classes after work. This is no longer the case for many who are interested to take these courses, so the courses are also offered online now.

Outside of Proficience and QIP, faculty members can also offer short-term courses, of varying duration. Upto 20 such courses are held each year, attended by around 500 participants. Courses are also conducted upon request from organisations such as BHEL, who send their employees for training.

Through such initiatives, students, college teachers and professionals who may not otherwise be able to attend courses at IISc "can come and experience for themselves the academic quality of IISc," says Narayanan. This also effectively serves as an advertisement for IISc, potentially enlarging, by word-of-mouth, the pool of students who apply for the traditional academic programmes at the Institute.

CCE participates in two national-level educational programmes, the National Programme on Technology Enhanced Learning (NPTEL) and Global Initiative of Academic Networks (GIAN) – these are coordinated by L Umanand (Professor, Department of Electronic Systems Engineering) and AG Ramakrishnan (Professor, Department of Electrical Engineering), respectively. CCE issues certificates on behalf of NPTEL for the courses conducted at IISc through this programme. It also conducts GIAN courses at IISc, where eminent international experts are invited to teach week-long courses – one or more IISc faculty as course coordinators – on specialised subjects.

In addition to conducting courses as part of these various programmes, CCE is also involved in supplementing the traditional curriculum. It has a Curriculum Development Cell which was, until recently, funded by the AICTE. It was meant to encourage faculty members to produce learning materials such as books. The Cell, now funded by CCE, still provides such support to faculty members, and has produced educational kits. A larger effort to reach out to school and college students is the Extension Lecture Programme, which sees faculty from the Institute volunteer to give talks on topics of their choice at schools and colleges across Karnataka who send in requests to the CCE office. This initiative, begun in 1990, was discontinued in 2010 but was restarted in 2016. This year, about 200 requests for lectures have been received from schools and colleges, says M Nethaji (Chief Research Scientist, Department of Inorganic and Physical Chemistry), the coordinator of this programme. About 50 such lectures were held last year, although the number of faculty participating is still small.

In fact, for all these programmes to suceed and grow, greater participation from faculty of the Institute is necessary. "I'd like to encourage faculty members to come forward and participate in the various programmes of CCE," says Sivakumar Babu.

Climate change, an evening in Paris, and a calculator from IISc to see into our future

Karthik Ramaswamy

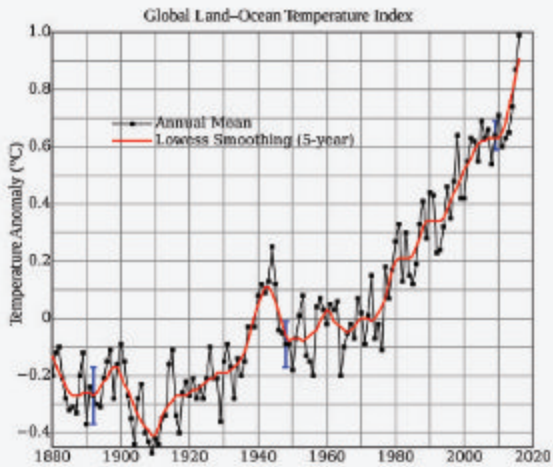
An interactive climate change calculator from IISc reveals the path we can take to ensure that global temperatures are kept in check. It also shows us the path to disaster

On a sunny spring afternoon last year at the Rose Garden in the White House, the US President Donald Trump made a sweeping proclamation. "We're getting out," he declared, referring to his intention of walking away from the Paris Agreement, which the US has not only signed, but also ratified. As part of the agreement, the US, the biggest carbon polluter in history, has promised to voluntarily cut greenhouse gas emissions by 26 to 28 percent in the next few years. If it reneges on its pledge, what would be the consequences for the global fight against climate change? There is no straightforward answer to the question, but we now have a climate change calculator to help us understand the repercussions of such a move. It has been developed based on research by Rajiv Kumar Chaturvedi, Senior Researcher at the Divecha Centre for Climate Change, and his collaborator Jeremy Woods from Imperial College London in the UK.

Since 1880, the average surface global temperature has increased by at least 0.85°C, and two-thirds of this warming has occurred since 1975. The effects of the change in temperature are already evident: sea levels are rising, sea ice and glaciers are melting, heat waves are becoming more frequent, and core ecological processes are being disrupted. And this is just Act One of the unfolding climate change drama because of a phenomenon that scientists call climate inertia– the delay in the earth's response to its warming.

The earth's temperature has been and continues to be influenced by natural factors like volcanic

Image courtesy: NASA/Creative Commons License/ Wikimedia Commons

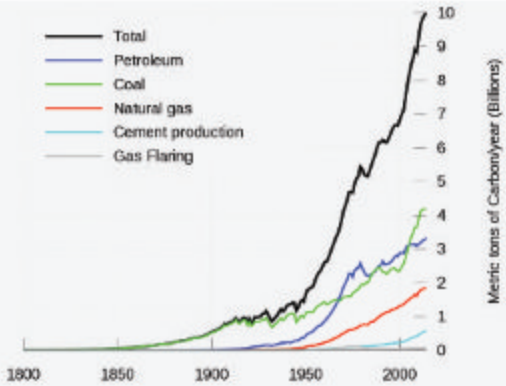


The dramatic increase in the average global temperature in recent human history

eruptions and solar irradiance. But the main villain in the recent spurt in warming which began with the industrial revolution is carbon dioxide (CO_2). CO_2 – called a greenhouse gas because it traps heat in the earth's atmosphere not unlike how glass traps heat within a greenhouse – is released by the burning of fossil fuels like coal, natural gas and petroleum, formed over millions of years from the remains of plants and animals.

This positive feedback makes CO_2 a deadly gas, and the principal driver of global warming

Surprisingly, CO_2 is not the most abundant greenhouse gas in our atmosphere. That honour goes to water vapour. However it is the increase in CO2 since the 1800s that has triggered the current surge in global temperatures. When the concentration of CO_2 goes up, it unleashes a chain reaction of sorts. Besides its own contribution to the greenhouse effect, CO_2 raises the humidity levels in the atmosphere due to evaporation from warming, which in turn amplifies the warming effect. The warmer temperatures melt ice on sea and land. Now this is a double whammy. Ice, being white, reflects most of the solar radiation that falls on it. The loss of ice increases the amount of incoming solar radiation absorbed which now gets trapped by the excess greenhouse gases. And when ice melts, it also increases the amount of water in our oceans. The excess water now absorbs additional heat. This positive feedback makes CO_2 a deadly gas, and the principal driver of global warming.

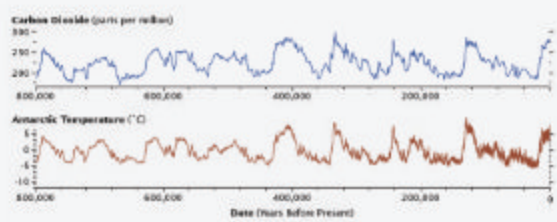


The corresponding increase in global carbon emissions from human activities

Image courtesy: Mark Thorpe/Creative Commons License/Wikimedia Commons

The amount of CO_2 in the atmosphere has increased from 280 parts per million (ppm) in 1750 to 406 ppm in the first half of 2017. And how much more CO_2 and other greenhouse gases we pump into the atmosphere in the coming years will determine how violently the earth responds to warming.

As we prepare for an uncertain future, the burden of making decisions to cut CO_2 emissions rests on the recommendations of policy makers and the political will of world leaders, leaders whose track record when it comes to fighting climate change has been sketchy at best. But on the evening of 12 December 2015, the world got an early Christmas gift when 195 countries came together in Paris and demonstrated a willingness to act on the impending global crisis.



The relationship between carbon dioxide and temperature in the Antarctic over the past 800,000 years obtained by studying ice cores which preserve information about our prehistoric climate. Studies have shown that changes in temperatures closely follow changes in carbon dioxide levels

Image courtesy: Creative Commons License/ Wikimedia Commons

The rare unanimity however comes at a price. As part of the agreement, each country determines its own emission target or NDC (Nationally Determined Contribution) which it will start to work towards meeting only in 2020. And unlike the Kyoto Protocol adopted in 1997, NDC targets are not binding and there is no central mechanism to enforce them.

In spite of its drawbacks, the Paris Agreement has a lot riding on it. But what happens if countries treat NDCs as mere lip service, given the non-binding nature of the agreement? Or what if they meet their ambitious targets? Or what happens if a country backs out of the agreement, as the US is threatening to do?

In the absence of another earth in which to do experiments, climate scientists address these issues by performing simulations with the help of mathematical models. The simulations predict the likely scenarios for global temperature changes assuming different emission levels in the coming years.

John Burn-Murdoch and Pilita Clark of the *Financial Times* have taken this a step further. Using the work of Chaturvedi and Woods, they have designed the COP21 calculator, an interactive tool hosted on the newspaper's website, to help us visualise how global temperatures could increase from what it was before the dawn of the industrial revolution. The virtual device is called the COP21 calculator after the official name of the Paris Climate Change Conference: the 21st Annual Meeting of the Conference of Parties – the countries that make up the United Nations Framework on Climate Change.

The COP21 calculator was developed when Chaturvedi visited Imperial College London in 2015.

Chaturvedi has a long association with IISc (he got his PhD from the Centre for Ecological Sciences and was later the National Environmental Sciences Fellow at the Centre for Sustainable Technologies). He describes the global calculator as the "precursor" to the one developed by *Financial Times*. "We from IISc had developed three scenarios for temperature increase for the global calculator. I used its algorithms for this calculator."

The calculator, which won the Royal Statistical Society's Statistical Excellence in Journalism award in 2016, is aimed at anyone interested in climate action, especially policy makers and world leaders. For instance, it can tell them what the global temperature increase is likely to be in 2100 if all the countries live up to the pledges they have made. "It also tells us what the scenarios will be if the major countries do what they are capable of doing beyond the promises they have made and also what might happen if they don't do anything," Chaturvedi says. The best and the worst case scenarios for emissions of each country, he explains, take into account the size of its economy, its expected economic growth and population growth. "For instance, EU emissions peaked in the year 1t979, but India will not be peaking in its emissions any time soon as it is a developing economy and has to grow. However, it is important that the new infrastructure is built with renewables and low carbon alternatives."

Photo: Tanuja Goyal

Rajiv Kumar Chaturvedi from the Divecha Centre. The climate change calculator is based on the research of Chaturvedi and Jeremy Woods from Imperial College London

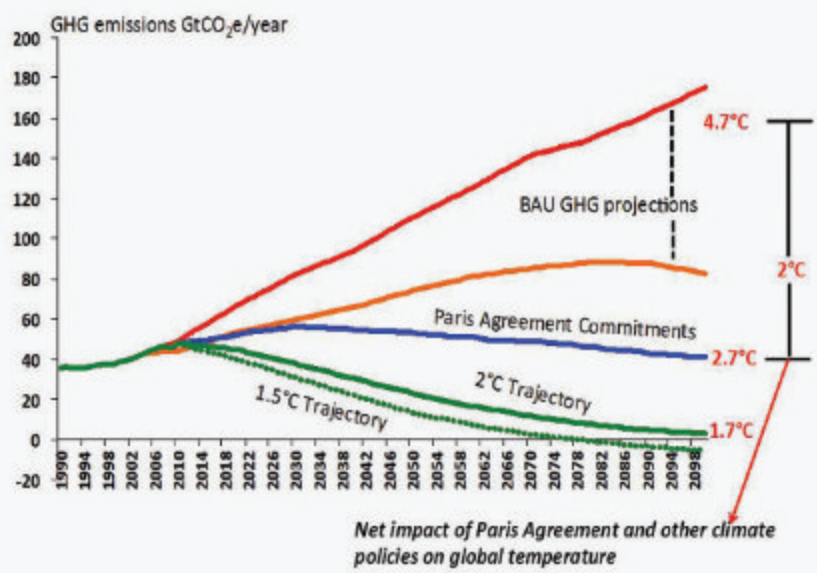
The calculator allows users to build their own models by selecting emission levels in one of three time periods (2020-2030, 2030-2050 and 2050-2100). Built into these models are greenhouse gas emissions from 1870 to 2012 for various countries. According to its projections, if all countries choose to do nothing to cut their emissions, the temperature increase will be about 4.7˚C (at a probability of 50%) and could be as high as a whopping 6˚C. The consequences of a temperature increase of 4˚C to 6˚C are likely to be disastrous for most life forms including humans. The world will see heatwaves so deadly in some parts of the world, especially the tropics, that it would be impossible for humans to survive even for more than a few hours. "If ambient air TW [wet-bulb temperature] exceeds 35˚C (typical human body skin temperature under warm conditions), metabolic heat can no longer be dissipated. Human exposure to TW of around 35˚C for even a few hours will result in death even for the fittest of humans under shaded, well-ventilated conditions," write Eun-Soon Im and her co-authors in a recent paper in *Science Advances*. "This will be an existential threat. It is not an option!" echoes Chaturvedi.

Climate scientists and world leaders are in agreement that we cannot allow a temperature spike of than more than 1.5˚C, or at worst, 2˚C. Holding global temperatures to this threshold is also the goal of the Paris Agreement. Even this temperature increase could have serious consequences for the planet, but may be the best possible outcome given how much greenhouse gas has already been pumped into the atmosphere. So will the pledges made at Paris help us keep the temperature increase to less than 2˚C? Unlikely, according to the COP21's computations. "Going by the current pledges, we may land up at around 2.7˚C at the end of the century. There is a fringe chance that this might even go up to close to 4˚C," Chaturvedi elaborates.

It is aimed at anyone interested in climate action, especially policy makers and world leaders

However, the genial climate scientist is not entirely pessimistic. "These targets are for the period 2020-2030. Some countries like India have plans to meet their target before 2030. And after that period, if all countries go this extra mile, we can still keep the temperature increase to less than 2˚C. So we have some leg room." But he ends with a warning. "It [the calculator] shows that the actions we take today are more important than the actions we take tomorrow."

And oh, if the US chooses to be indifferent to its Paris pledge and long term climate goals, while all the major economies keep their promises, Chaturvedi's model shows that the temperature rise will be greater by about 0.3˚C.

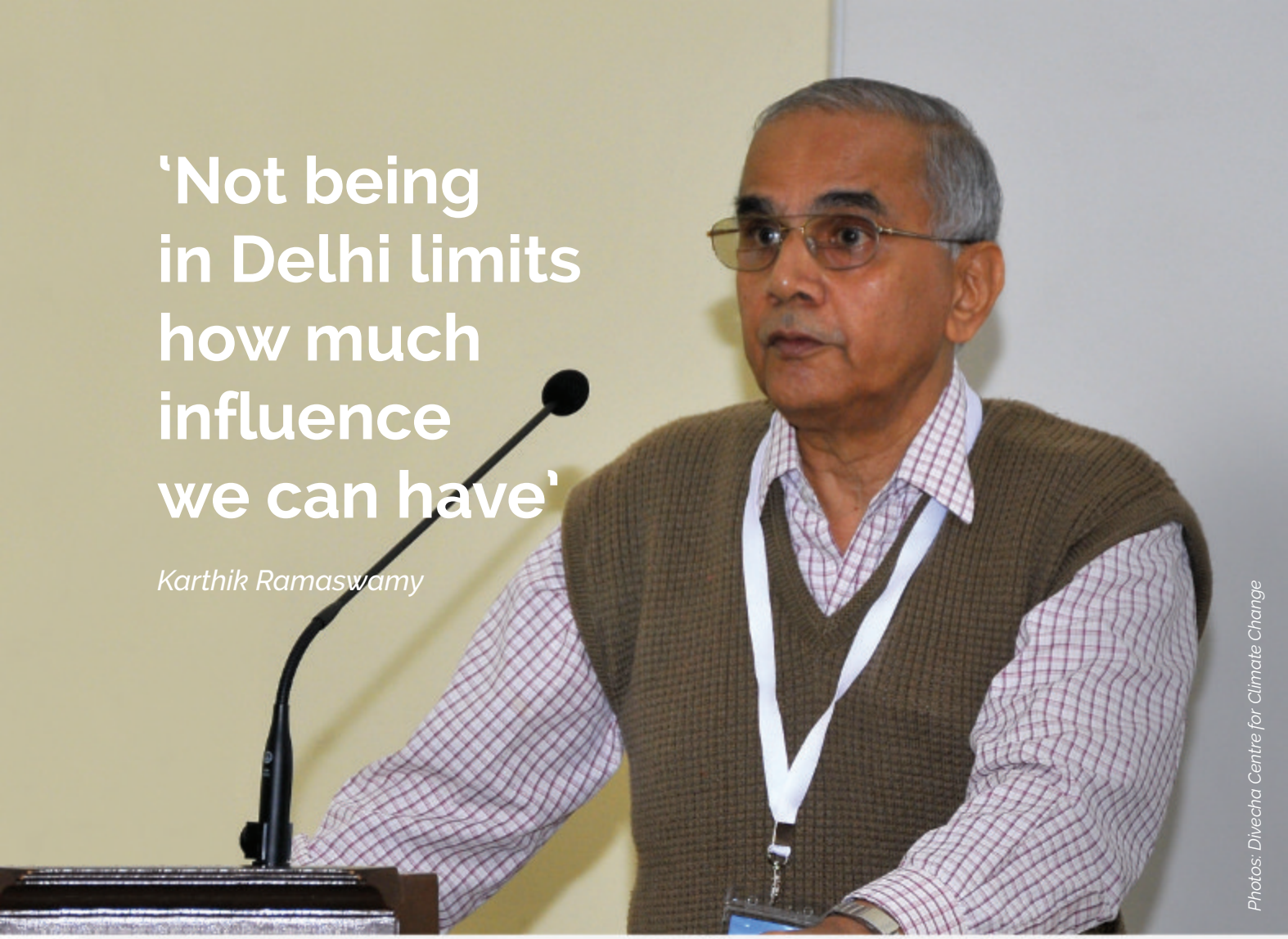


The net impact of the Paris Agreement and other climate policies on global temperatures according to the projections of the COP21 calculator (BAU = Business as usual; GHG = Greenhouse gases); Note: Temperature projections at 50% probability

Image courtesy: Rajiv Kumar Chaturvedi

'Not being in Delhi limits how much influence we can have'

Karthik Ramaswamy



Photos: Divecha Centre for Climate Change

The Divecha Centre for Climate Change was set up in IISc in 2009 with funding from US-based philanthropists, Arjun and Diana Divecha, and the Grantham Foundation for the Protection of the Environment, founded by British investor Jeremy Grantham. Since its establishment, the Centre has focussed primarily on research and on raising awareness on climate change issues.

Up until last year, the Divecha Centre was headed by J Srinivasan. Srinivasan's association with the Centre continues – he is now a Distinguished Scientist. In a brief interview to* Connect*, he spoke about yet another goal of the Centre: to help shape policies on climate change, and the hurdles it faces in this endeavour.

What was the mandate of the Divecha Centre when it was set up?

When the Divecha Centre started, we, being from a science institute, were very keen on doing research. Arjun Divecha and Jeremy Grantham said, "Fine, if you're happy doing science, we'll support that. But you have to do two more things. You have to do a major outreach effort so that your science gets known to the public, and secondly, you must engage with the government so that you have some influence on government policy." So since that time, we've been involved in engaging with the government, but not as much as we would've liked to.

In what ways have you engaged with the government?

At the Divecha Centre we now have many faculty with expertise in different areas. They are part of committees in ISRO, Ministry of Earth Sciences, Ministry of Environment and Forests (MoEF) and Department of Science and Technology. So we've been involved in discussions on several issues where we provide our expertise. And this has some impact. Take for example the current emphasis on solar energy. I've been arguing for solar for the last 40 years. Not many took me seriously. They would say things like, "It is not practical, it is costly, it is unreliable, there's not enough land." But slowly the viewpoint has changed.

In fact, well before the Divecha Centre started, in 2002, we [the Centre for Atmospheric and Oceanic Sciences] made a big impact during the Asian brown cloud controversy [researchers from the Centre provided clarifications on several claims in the aftermath of a report published by the United Nations Environmental Programme (UNEP) on a layer of air pollution seen over parts of Asia during the winter months]. India had to fight a case in the UNEP meeting. And at that time, we wrote detailed position papers on why their argument was not right.

People in Delhi always consult us just as they consult other stakeholders and I'm sure that our input goes into their thinking

So whenever the government needs any input, they consult us. Even recently, I got an email from MoEF seeking inputs for an IPCC [Inter-Governmental Panel on Climate Change] meeting on the Asian brown cloud issue which we thought had been resolved. It is now called short-lived climate pollutants. We're saying that we should not get distracted by this issue and instead must keep our eyes on reducing CO_2 emissions. So people in Delhi always consult us just as they consult other stakeholders and I'm sure that our input goes into their thinking. But you must remember that we are not a full-fledged policy centre.

What are the hurdles that the Centre faces in being more active in shaping climate policy?

Not being in Delhi definitely limits how much influence we can have. See, whenever the government has to make a decision, they consult people who are available immediately. They call a meeting, have a discussion and make a decision. So most people who have serious policy interests have to be in Delhi. All the major policy-related institutions and NGOs will have at least one office in Delhi because they know that at very short notice, people are called for consultations.

I would also argue that a big weakness of our Institute is that we don't have a social sciences or humanities department. Research in these fields was part of the vision of our founder JN Tata. I can tell you that about 30 years ago, JRD Tata [who was also the President of the Court of IISc] reminded the Institute that that was in the charter and tried very hard to convince us to start such a department. And there have also been attempts to make the Management Studies Department focus more on policy issues. Though Prof Amulya Reddy [former Chairperson of the Management Studies Department] and Prof Balaram [former Director of IISc] tried very hard, it didn't happen. But I think the Institute needs to have a proper humanities and social sciences department which should be interacting with all the science and engineering departments.

I must also point out that researchers working in these fields in places like TISS [Tata Institute of Social Sciences, Mumbai] or in other such institutes don't interact much with scientists either. So to me both sides do not understand each other. This I think is a major limitation. If we want to make a proper policy in the area of climate change, we need to understand the science, know how to communicate the science, and know how to formulate policies.

If we want to make a proper policy in the area of climate change, we need to understand the science, know how to communicate the science, and know how to formulate policies

On our part, even though we don't have such a department, we at Divecha have tried to find someone to look at policy issues. But people who have serious policy and policy research interests tend to go to IIMs or even IITs where there are big departments in social sciences and humanities. They think that they may not fit here in IISc because it is a pure science institution. But now we are working even harder to get a policy person, something that the Director [of IISc] is also very keen on. I'm sure it'll happen soon.

Nanotechnology for the Nation

Nithyanand Rao

The Indian Nanoelectronics Users' Program (INUP) at IISc and IIT Bombay is training researchers across the country to build national capability in nanoelectronics

Photos courtesy: INUP/CeNSE

Since it began in 2008, the Indian Nanoelectronics Users' Program (INUP) has received exceptional positive feedback from its participants. Among them are college teachers who say that their participation in the training programme helped them become better teachers because they had the opportunity, for the first time, to handle silicon wafers – the critical component used to fabricate the innards of electronic devices.

"This was a completely unanticipated benefit," says SA Shivashankar, a visiting professor at the Centre for Nano Science and Engineering (CeNSE), IISc. "It wasn't a part of our proposal at all." (Shivashankar was the Principal Investigator for INUP until he retired in 2012.)

College teachers say that their participation in the training programme helped them become better teachers because they had the opportunity, for the first time, to handle silicon wafers

The idea behind INUP is simple: The state-of-the-art facilities and the expertise at CeNSE would be made available to the wider research community in India to work on their ideas. These are projects they would otherwise have been unable to work on because they didn't have access to the facilities nor the training to use them.

INUP is part of a larger effort to meet the goals of the National Policy in Electronics: to build up national capabilities for a larger electronics R&D and industry base that can serve the domestic and export markets rather than having to rely on imports. "We [India] missed the bus for the microelectronics revolution. The government didn't want it to happen for nanoelectronics too," says Navakanta Bhat, Chairperson of CeNSE and the present Principal Investigator of INUP. "The aim is to create human resources in this area, a critical mass of people who can contribute. This will create a 'multiplier effect', where the people we train will go out and influence others."

INUP is supported by the Ministry of Electronics and Information Technology, which funded the Centres of Excellence in Nanoelectronics at IISc and IIT Bombay. These two institutions were then tasked with implementing INUP, making available their facilities to researchers from around the country.

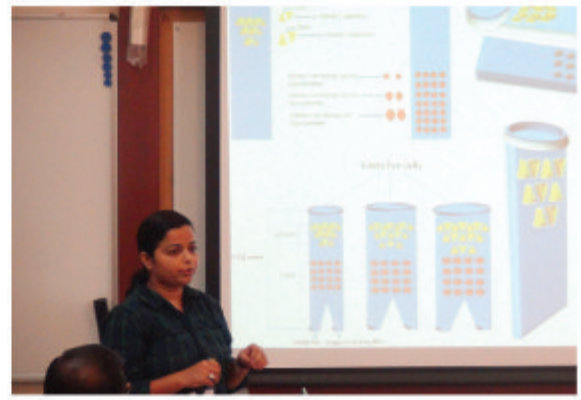
The three-level programme is open to PhD students and faculty members at institutions across India. For the Level 1 Familiarization Workshop, about 100 participants attend lectures for three days, and get an introductory tour of the facilities at CeNSE. These are participants who, as part of the application process, have submitted a poster outlining a proposal for research using the facilities at CeNSE. Over the years, it was found that participation from certain parts of India, such as the northeastern states, was low, which prompted proactive seeking of participants from these regions by conducting

Level 1 programs there. Such outstation workshops, which have been conducted in Uttarakhand and Rajasthan too, now form one of about half-a-dozen Level 1 workshops offered each year.

Participants who have attended a Level 1 course, or who are otherwise eligible, attend a Level 2 Hands-on Training workshop at the facilities at CeNSE. This is a two-week programme for about 30 participants, consisting of four modules: on MEMS/NEMS (micro/nano-electromechanical systems) fabrication, nanoelectronics fabrication, photovoltaics, and gas sensors. These modules are run in parallel with five to seven participants each, training them on the tools that can be used to realise their research proposal. CeNSE is especially suited for such training, given the facilities it has for everything from fabrication to packaging, not usually found together, in the form of the National Nanofabrication Facility, the Micro and Nano Characterization Facility, the System Engineering Facilty, and the MEMS & IC Packaging Facility. "These facilities at IISc are comparable to the best in the world," says Bhat.

At the end of the Level 2 workshop, the participants have to make a presentation with a detailed research proposal, where they receive feedback from faculty members and technical staff at CeNSE. "Based on these inputs and the training they have received, they may have to modify their research proposals, and members of faculty and the technical staff here help them do that," says Sanjeev Kumar Shrivastava, Coordinator and Technology Manager of INUP. They then have to resubmit their proposals, which are evaluated by a committee. Some are asked to modify their research proposal further, and selected participants come back to work on their proposed project – the third level of the programme. "At any point of time, there are one or two people here doing long-term projects," says Shrivastava.

In its Phase I, from 2008 to 2014, INUP exceeded its targets. It is currently in its Phase II, which will last till 2019 – but the targets have been met in just two years. So far, INUP has trained more than 4200 researchers from 450 institutions across India, covering a wide swath of institutions, including some of the IITs and NITs. Many participants come from smaller, lesser-known, private engineering colleges, some of whom have gone on to file for patents for their work. This has resulted in more than 250 PhD theses based partly or wholly on work done through INUP at CeNSE; it has also resulted in about 210 published papers and 17 patents filed/awarded. The projects they have worked on range from synthesis of nanomaterials and nanostructures to fabrication of nanodevices and characterisation of their performance.



A participant of a Hands-on Training Program presenting her proposal

All this work means that more than a dozen papers are published every year as part of INUP, none of which have IISc faculty as co-authors, a deliberate policy. "It is their work. They have taken the initiative and put in the work," says Bhat.

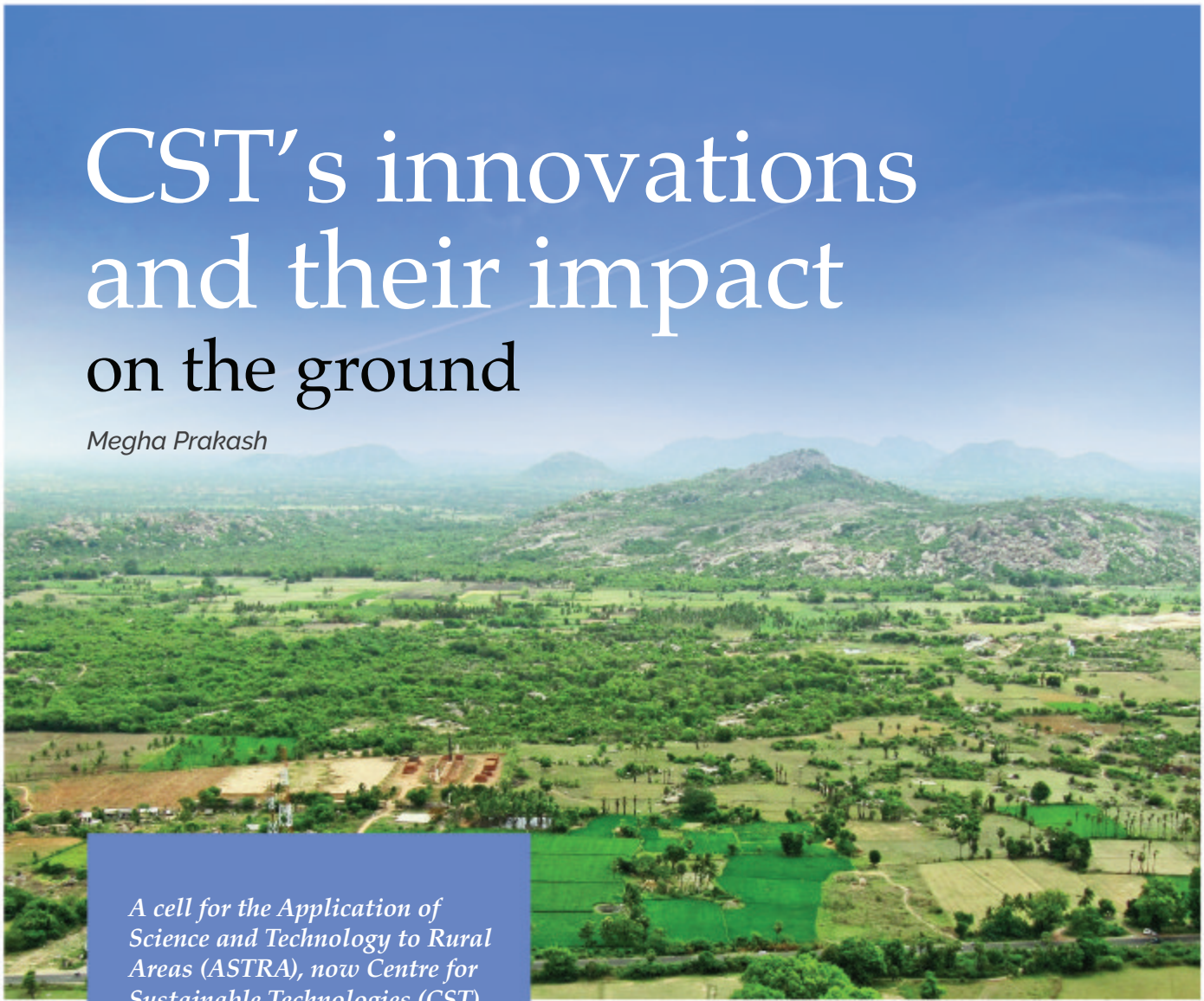
The training programme has now been offered for researchers from India's neighbouring countries too – such as Sri Lanka, Bangladesh, Myanmar, Maldives, Vietnam, and Kazakhstan – through the Indian Technical and Economic Cooperation (ITEC) programme of the Ministry of External Affairs. Further, India's experience with INUP was presented at the University/Government/Industry Micro/Nanotechnology (UGIM) Symposium – a prominent conference in the field of micro/nanotechnology – where, Bhat says, representatives from other countries expressed interest in replicating this programme. Unlike other such networked training programmes elsewhere in the world, participants of INUP – who may find it difficult to obtain research grants – do not have to pay for access to the facilities. In fact, their travel and accommodation costs too are taken care of. "This frees them up to focus on their work here," says Bhat. They also get to tap the expertise of faculty members at IISc.

Through its website, INUP has made efforts to network its participants with one another and with prospective participants. A student or faculty from a particular institution, for instance, can look up who else has participated from their region and get to know what kinds of projects have been implemented.

Based mostly on word-of-mouth communication, INUP has seen an increasing number of applicants over the years. "Its popularity, with the increasing participation, shows that it's been a resounding success," says Shivashankar.

CST's innovations and their impact on the ground

Megha Prakash



A cell for the Application of Science and Technology to Rural Areas (ASTRA), now Centre for Sustainable Technologies (CST), was created in 1974 to initiate and promote work of rural relevance as a weapon against poverty. IISc's then Director, Satish Dhawan, who was deeply concerned about science and society, invited Amulya Reddy [a professor of electrochemistry who went on to found CST] to make presentations to the Senate Committee on Research and Academic Policy and design a multi-disciplinary centre which would draw expertise from the various discipline-oriented departments at the Institute.

True to its initial mandate, the technologies developed at the Centre over the years have not only benefitted communities by building eco-friendly toilets, low-cost houses, providing clean drinking water, fuel-efficient cooking stoves or meeting needs of farmers, but have also helped policy-makers frame policies at the global level.

To find out how these technologies developed at CST are helping society, Megha Prakash travelled to villages in Karnataka and Tamil Nadu, where some of these award-winning technologies have been transferred and implemented in partnership with NGOs and the community.

Building technologies

Selva Rani sees the 2004 tsunami as a life-changing event. Before the tsunami, she lived in a thatched hut. But today, she has a comfortable life with her family in her house built using technology developed at CST. Rajendra and Lalitha, a couple who are among the many rehabilitated on the island of Kodiyampalayam, are happy too. They have recently painted their pad to welcome their son's bride. "Moving into this house solved our problem – the rains. Our thatched hut used to leak and the keet (palm-leafed roof) had to be changed once in a while," Rajendra tells me.

Photo: Megha Prakash

Low-cost housing and sanitation in tsunami-hit Kodiyampalayam, built using fly-ash stabilised blocks

This is one such success story, where a technology that took over a decade to develop is helping the community improve their lives. In Kodiyampalayam, an island 20 kilometres off Chidambaram in Tamil Nadu, this housing and sanitation project was undertaken by CST in 2006. In all, 140 toilet units along with 140 housing units were built for the tsunami-struck fishing community. This project was implemented in partnership with an Ahmedabad-based NGO, Centre for Environment Education.

To scientifically develop this sanitation design for Kodiyampalayam, Monto Mani (Associate Professor, CST), first had to understand the problem. It was not just about building a toilet because the local topography, environment and other challenges on this island were different. The primary challenge was to design toilet units in crammed spaces where the conventional septic tank could not be built due to space constraints. Second, the drinking water table, unlike in coastal regions, was very high (3-4 ft) in this region, and hence the design had to be such that the water is not contaminated. After much thought and a year, a suitable toilet unit design was proposed.

What makes this design unique, according to Mani, is its functionality even in a flood-like situation. The toilet units are built on a raised platform, where the C-shaped septic tank is divided into two compartments – unlike in the conventional design. Also, these structures can be built in congested spaces using locally available construction material without skilled labour. "The design was scientifically developed to dissipate water close to the ground surface instead of into the ground where it risks groundwater contamination," adds Mani.

This improved toilet design, which was patented, later received 'best practices' recognition and a letter of commendation from the Suez Environment-Water For All Foundation (a French multinational company) as one of the top four designs or technologies that support safe water.

The housing structures, including the toilet units, were built using rammed earth technology developed by BV Venkatarama Reddy (Chairperson, CST and Professor of Civil Engineering). But designing was a problem because local construction materials weren't readily available, and also because of salinity and coastal erosion. To solve these problems, fly ash, a by-product from a nearby coal mine, was used as the material to build the blocks – minimising the use of steel and hence reducing structural corrosion. The villagers were also trained to use the manual press machine to make fly-ash blocks and cure their own homes. As a result, each housing unit was built in 6-7 months. For all these reasons, Reddy says, the housing project in Kodiyampalayam is an excellent example of community participation.

But, because problems and requirements vary from region to region and community to community, implementation becomes challenging. For example, the sanitation requirements of the villagers of Pallerayanahalli, a village close to Ungra in Kunigal taluk of Tumkur district in Karnataka, were different from those of the residents of Kodiyampalayam. Though the water table in Pallerayanahalli was low, the community wanted wet toilets. Based on this understanding, eco-san (a toilet technology) prototype was developed at CST's Ungra Extension Centre.

Since then, both the rural housing and sanitation designs developed at CST have been replicated and are being used by several eminent architects in the country. More recently, 350 villas in Good Earth's commercial venture, the Good Earth Malahar housing project in Bengaluru, were built using the stabilised mud block technology developed at CST. Besides the technology, the machine, ASTRAM-10, used for making the mud blocks is now commercially produced and sold.

According to Reddy, more than 100,000 independent buildings have been built so far using this alternative building technology – resulting in 2.5 to 3 million tonnes of carbon savings.

The Good Earth Malahar Housing project used stabilised mud block technology to build 350 villas in Bengaluru

Photos: BV Venkatarama Reddy

In participation with a local NGO, Hunnarshala Foundation, 10,000 circular houses (or bhungas, in the local language) were built using rammed earth technology in earthquake devastated Bhuj in Gujarat

Bio-energy and gasification

Another area where CST has had expertise for long is bio-energy and gasification. In 2015, HN Chanakya's (Chief Research Scientist, CST) design of a novel biogas reactor gave further impetus to the Centre's work on bio-energy, bio-methanation and wastewater management. Highlighting the uniqueness of the bio-gas reactor, Chanakya says that the reactor developed by his team can use plant or agriculture waste, and not just cow dung like a traditional gobar gas plant. It can also use the digested residue as a substrate to grow mushrooms (about 2.32 kilograms of mushroom per kg of the substrate).

On the other hand, S Dasappa's (Professor, CST and Combustion, Gasification and Propulsion Laboratory) work on thermo-chemical conversion of biomass has led to development of various technology packages, and these products have been successfully commercialised through technology transfer. For instance, General Electric (GE), which in 2015 licensed the biomass gasifier technology that generates electricity from agro-waste and wood from IISc, will help Phoenix Energy set up power plants in California, USA.

Creating a livelihood

During demonetisation the farming community was threatened. Crops were ready for harvest but largely remained untouched as farmers found it difficult to pay cash to farm labourers due to currency shortage. In this time of crisis, CST's fuel-efficient ASTRA vegetable and fruit drier came to the rescue of many farmers. In Pandavapura taluk of Mandya district, Karnataka, this innovation is helping not only farmers and farm labourers, but even rural womenfolk earn a livelihood through it by forming self-help groups. This technology has been taken up by Technology Informatics Design Endeavour (TIDE), an NGO, to extend its reach among the farming community in Karnataka.

Photos: Megha Prakash

ASTRA vegetable and fruit drier

According to HI Somashekar (former Technical Officer, CST) this technology has met with huge success in and around Sirsi in Uttara Kannada district. "The technology completely dehydrates vegetables, fruits, spices, and even fish and prawns while retaining their nutrition levels and flavours before packaging them in powdered form," says Diwekar Bhat, who has been using this technology to dry areca nut in his farm in Sirsi. "It can be readily used in preparing dishes like sambar, pickles, pulao, or curries, with their natural flavours intact."

Serving the cooking needs: ASTRA OLE

From finding place in community kitchens to schools and houses, ASTRA OLE is both energy- and fuel-efficient. In partnership with IORA Ecological Solutions Pvt. Ltd., an NGO based in New Delhi, CST has been training young boys from villages in rural technologies like fuel-efficient cooking stoves (ASTRA OLE), sanitation, rammed earth stabilised mud block technology, ASTRA drier among others. In less than a year since the training programme began in 2016, more than 10 young boys were trained at IISc's Challakere campus – they are now working in 25 villages in Sirsi, where they have built 20 cooking stoves and six bath water heating stoves.

"The stove cost us Rs 2,500, including labour, making charges and locally procured raw material," says Keshav Marya Nayak of Shigehalli village in Sirsi tehsil of Uttara Kannada district. Nayak saw this stove in the home of Kiran, one of the trainees at CST. For Chandrakala, another user of the cooking stove since June 2017, life is a bit easier now – cooking time has reduced, and she now has more time for other chores and for her family. "I have to collect less firewood, there is no smoke, no soot, and hot water can be used for washing vessels, bath and cooking," says Chandrakala, listing the advantages of having an ASTRA OLE.

Top: ASTRA OLE cooking stove at Huliappa's Donne Biryani in Yelahanka; Bottom: ASTRA OLE customised for roti-making for an ashram in Kengeri on the outskirts of Bengaluru

Photo: Megha Prakash

ASTRA OLE cooking stoves at The Valley School in Bengaluru

ASTRA OLE cooking stoves are now used at commercial and non-commercial establishments. An ashram in Kengeri on the outskirts of Bengaluru, for example, serves 150 hot meals daily on an average, all cooked on ASTRA OLE stoves. The Valley School, Bengaluru, which has 7 cooking stoves, serves 500 meals per day and is completely off LPG cylinders. A jaggery park in Mandya too uses a modified version of the stove. Vishnupriya Hotel located on Commercial Street, Bengaluru, has been able to reduce the number of commercial LPG cylinders they use from 100 cylinders a month to 20-22, while Huliyappa's Donne Biryani in Yelahanka, Bengaluru, find the ASTRA cooking stove an eco-friendly option and dish out around 500 plates of chicken biryani daily. ASTRA OLE also allows Nandakumar, owner of a hotel in Devanahalli, to slow-cook traditional recipes for flavour and nutrition.

Technology adoption

Even if a technology developed works as intended, getting people to adopt it can be a challenge. "Fortunately, the villagers in the areas where we worked developed faith in the solutions we offered," says Reddy. The technologies developed at CST are a work of labour and time, many of them took decades to develop, and the process continues even today. While these technologies have made a difference to the lives of many living in rural clusters, their reach is still limited to a miniscule number of people in the country. The reason why CST has not been able scale up, according to NH Ravindranath (Professor, CST), is lack of will or interest on the part of the government agencies to adopt and disseminate these technological solutions to a larger population.

Moving into the future

Punit Singh (Assistant Professor, CST) is currently engaged in implementing a project in Chhattisgarh for an un-electrified tribal village situated in a forest (Bastar district), but blessed with a gradually-sloped perennial stream. He has designed, manufactured and tested an innovative low head hydro-turbine integrated to a generator and pump as one 'single unit'. The idea is that this can be used to alternatively supply electricity and pump water to higher locations for irrigation and drinking water needs of the people. This project, currently being implemented, will create ecological and human interdependence ensuring sustenance, Singh says. In future, he intends to focus on innovative and challenging turbomachinery for renewable energy covering both hydro and thermal applications.

In line with UN's Sustainable Development Goal 6 of ensuring access to water and sanitation for all, Laxminarayana Rao (Assistant Professor, CST), has developed a new method of recycling greywater – that is, non-industrial wastewater from domestic sources such as dish-washing, laundry and bathing. Upto 75 percent of all water used in homes can be classified as greywater. Remaining 25 percent of domestic wastewater, originating from toilets and flushes, is termed as blackwater.

Rao says that, in many countries, greywater is being reused for various applications like flushing toilets, irrigation of lawns, washing of vehicles and windows, fire protection, boiler feed water and concrete production, amongst others. But there are many problems associated with reuse of untreated greywater. It may increase the risk of spreading diseases due to microbial growth in water. It may also result in elevated concentrations of detergents in the soil when reused for irrigation. Though there is a strong initiative to recycle water, much of the efforts are hindered by the socio-psychological biases.

The method developed by Rao uses ozone generated from dielectric barrier discharge (DBD) cold plasma based reactor. For in-house applications, a compact DBD-based ozone generator was designed as commercial units are bulky. "Based on the positive laboratory results, a decentralized greywater recovery system for a school in rural India is being designed," says Rao. This school, he says, has about 200 students, 5 staff members and 5 support staff, and consumes around 2500 L per day of fresh water drawn from a borewell nearby, out of which about 1500 L ends up being used for washing hands or dishes. The remaining 1000 L is used in the toilets. In the first phase, about 1000 L of greywater – water from the handwash and the kitchen sink – will be treated and reused as toilet flush water. The project is currently in its implementation stage.

Meet Lakshmi Sita

Rohini Krishnamurthy

The former IISc professor is a biotech pioneer who mass-produced sandalwood trees from test tubes

Sita explaining her work to Prince Charles

In the summer of 1976, a young scientist named Lakshmi Sita joined IISc as a post doctoral fellow. She had just completed her PhD after working on growth substances and tissue culture of sweet corn from Victoria University in the UK, and on her return to India, she was asked to work on a problem that had plagued forest officials in Karnataka for close to a century.

In 1891, a Forest Department official named McCarthy noted in his progress report for that year that the leaves and internodes of certain sandalwood trees in Coorg (now Kodagu) had become smaller and stiffer. With time, the entire shoot started to resemble a "spike" inflorescence, and the trees died in two or three years. In the late 1920s, in order to investigate the cause of spike disease, scientists at IISc began working with the Government of Madras and the Coorg Commission. The disease–called sandalwood spike disease–continued to puzzle scientists globally until 1969, when it was confirmed that the causative agent was mycoplasma, a parasitic bacteria.

The disease was devastating. Nearly a million trees were removed from Mysore and Coorg between 1903 and 1916. As sandalwood is used in the perfume and wood industries, the government of Karnataka incurred huge losses in the years that followed. This prompted scientists at IISc to look into the problem. And when Sita joined the Institute's Department of Microbiology and Cell Biology (MCB), it was suggested to her that she use her expertise in plant tissue culture to develop disease-resistant sandalwood trees.

followed. This prompted scientists at IISc to look into the problem. And when Sita joined the Institute's Department of Microbiology and Cell Biology (MCB), it was suggested to her that she use her expertise in plant tissue culture to develop disease-resistant sandalwood trees.

Initially, plant breeders banked upon a type of asexual reproduction called vegetative propagation, through which a single plant produces clones of itself. Though this occurs naturally – as in potatoes – it can be induced artificially as well.

To induce vegetative propagation in trees, foresters would select trees that were inherently resistant to attacks by a pathogen – in this case, mycoplasma. However, they could produce only a limited number of plants by this method thereby limiting large scale plantations.

So they turned to tissue culture. Plants are totipotent, which means a single plant cell can develop into an individual plant. Exploiting this property, plant biotechnologists transfer a portion of a plant to a test tube containing a synthetic and sterile medium which is a source of nutrients.

Test tube trees

Unlike with herbaceous plants, culturing trees in a test tube poses significant challenges. Before Sita's attempts, scientists hadn't managed particularly well: although L Winton from the Institute of Paper Chemistry in Wisconsin tasted some success performing experiments on a deciduous tree – aspen – but he managed to produce only four surviving trees.

Determined to find a solution, Sita used nodes and internodes from disease-free trees as starting material to produce millions of unspecialised cells called callus. In a process called somatic embryogenesis, she directed these unspecialised cells to form embryos and then the embryos to sandalwood plantlets. In a few months, Sita had hundreds of plants in her lab.

Image courtesy: Lakshmi Sita

Various stages of development in tissue cultured sandalwood

Cultivating an organism in a test tube is not a straightforward process; scientists are still trying to understand how simple cells develop into complex organisms. But Sita took a chance, and painstakingly developed this technology.

Sita's technique brought down harvesting time. She showed that the heartwood (the central part of the wood known to give sandalwood its characteristic fragrance) from a seven-year-old tissue cultured sandalwood tree was almost equal to that of a 40-year-old naturally grown tree.

Next, she focussed on other commercially important trees like rosewood, eucalyptus and teak. Even to this day, one can see sandalwood and rosewood trees that were grown from tissue cultures, planted near the old MCB building, although the rosewood in the quadrangle has no label indicating its origin. It is unfortunate that few are aware of these trees, which were once widely celebrated.

After her stint as a post doctoral fellow and as a Senior Scientific Officer, Sita went on to become Professor at MCB. Her plant tissue culture lab soon became a star attraction. From Prince Charles to Rajiv Gandhi and Ratan Tata, several visitors were directed to the lab. "This is one area [of research] where people can see the transition from lab to field. Visitors were sent to the MCB department to show them what science can do," says 78-year old Sita, as she looks at old photographs, during an interview at her home in Malleshwaram.

Photo courtesy: Lakshmi Sita

Sita within Ratan Tata during his visit to her lab.

Trees out of test-tubes

BANGALORE

TO MANY of us, living in the northern part of Bangalore City, the Tata Institute more commonly known as the Indian Institute of Science, is a vast piece of land full of flowering trees of various colours providing shade and fresh air in the hot summer mornings when we go for a stroll.

We hear the variety of birds sing. As we come out, the scientists and students enter the institute with a different purpose and pursuit. The sound of the birds is replaced by machinery and people.

Here, they produce many things. Among them, scientists, particularly Dr. Leonl Swetha, have produced a few hundred sandal plants by tissue culture method, in test-tubes in the laboratory feeding mineral nutrients. Some of them have been planted in the institute premises for observation.

The silviculturist, Karnataka Forest Department, Bangalore, obtained some test-tube plants and for field trial planted one tree inside the Mudigere Research Garden. The sandal has put up a very good growth height of over 12 feet in three years and has an unusual type of bushy branching right from the ground level unlike in other trees. While the tissue culture method is not new to scientists, this surviving plant is perhaps the unique one in India. If these test-tube sandal trees can resist the deadly disease of spike on Sandal, the future of the green gold is bright in Karnataka

Pic. & Text By K. N. S. IYER.

Deccan Evening Herald Vol. 1 No. 10. dt August 28th 1983.

Her work also piqued the interest of the Forest Department. Swaminath, a silviculturist (someone who looks after forest trees) from the Department planted the tissue-cultured sandalwood in a nursery in Mudigere, Karnataka.

Sita points out that it is not feasible to assess the quality in a short time since trees take a long time to reach maturity. Establishing the tissue cultured plants into soil is a delicate process. The tissue cultured tree also needs to breed true – passing traits to its offspring – to prove beneficial in the long run. "I have given some pieces to the Forest Department."

Venturing further

Sita's scientific exploration didn't stop at trees. Through the 1980s and 90s, as the field of genetic engineering began gaining traction, Sita and her students wanted to create transgenic crops by introducing genes into plants that equip them with improved characteristics such as disease resistance or increased yield. They worked on tomatoes, capsicum, brinjal, groundnut, red gram, and cotton, among others.

Plant biotechnologists hail transgenics as a solution to food scarcity and plant diseases, which cause massive losses to farmers.

Transgenic plants don't just find applications in the agriculture sector: in 2001, two scientists, Charles J Arntzen and Dominic Man-Kit Lam, produced a potential vaccine candidate against Hepatitis B using transgenic tobacco plants.

Inspired by this technology, Sita joined hands with molecular virologist MS Shaila, who is now Emeritus Professor at the MCB department, to use transgenic plants to create edible vaccines against fatal viral diseases – such as rinderpest in cattle – as an alternative to a more sophisticated and expensive cell culture technique.

As part of their research, Shaila and Sita introduced a rinderpest protein, hemagglutinin (H) into peanut plants. They fed this transgenic plant to cattle, hoping that the cattle would produce antibodies against the ingested protein. Finding specific antibodies in the blood of the tested cattle meant that some of these antibodies stayed back as memory cells, protecting the immunised animal if rinderpest were to attack again.

The team was ecstatic that this could pave way for animal trials. Unfortunately, as India was a part of a global eradication campaign to eradicate rinderpest at the time, the World Organisation of Animal Health and Food and Agriculture Organization of the United Nations "laid out rules that virulent disease-causing virus strains should not be handled by researchers in any institution, other than [the] identified institution, which was Indian Veterinary Research Institute," says Shaila. The disease was eventually globally eradicated in 2011. Later, Sita also developed virus-resistant cotton plants.

Sita retired in 2001 after having worked on an array of issues that are central to crop improvement. Extensive field trials have to be conducted to assess the safety of plants and this requires substantial funding. "People do not usually accept new technology easily unless there are a lot of financial gains."

In addition, there is a growing opposition to transgenics: a fear that inserting genes could have deleterious effects on the body and the environment. So far, Bt cotton is the only approved transgenic crop in India.

According to Sita, approval of transgenics should be similar to that of drugs. Elaborating on this, she says, "Drugs could be withdrawn from the market if someone shows its negative impacts. The same can be done with transgenic plants. It takes about 20 years for a drug to come out – tests in the lab, on animals and humans have to be performed." She insists that one must draw conclusions only after studying its long-term effects.

Co-founders Fathima Benazir (left) and Alex D Paul (centre), R&D Associate Harshini Nadig (right)

Photo: Rohini Krishnamurthy

This IISc-incubated company has its sights set on a global market

Rohini Krishnamurthy

Fathima Benazir and Alex D Paul were classmates in school. Many years later, Fathima, a postdoctoral fellow at IISc, began looking for opportunities abroad and happened to share her research with Alex, who worked in the corporate sector. Alex, after going through her work, encouraged Fathima to come up with a product that could have a huge business impact and "not bury her work in big books". And this is how Fathima and Alex collaborated and co-founded Azooka Life Sciences.

Azooka Life Sciences was formed in July 2015 and was incubated at the Society for Innovation and Development (SID), IISc. In March 2016, they released the first ever food-grade nucleic acid dye, named "tinto rang". Molecular biologists use such dyes to detect DNA and RNA in their experiments.

Azooka is now locking horns with giants like Merck and Sigma Aldrich who are the biggest suppliers of ethidium bromide (EtBr), the most commonly and widely used nucleic acid dye. But EtBr is a known potent mutagen. Offering molecular biology labs a safer environment by doing away with harmful dyes and the accompanying process of disposal, Azooka plans to take over the speciality fluorescent dye/probe industry one step at a time. In conversation with **Connect**, *Fathima and Alex share their stories of positivity despite roadblocks and their thoughts on Azooka's future.*

What was life like before Azooka?

Fathima: I've always been passionate about science right from school, more so towards biology. I obtained my Master's and PhD, both in environmental biotechnology, with specialisation in plant biotechnology. I did my postdoc in x-ray crystallography at Prof MRN Murthy's lab at MBU [Molecular Biophysics Unit] as a Dr DS Kothari Postdoctoral Fellow. I'm happiest while working in the lab. I did not plan to make this transition to entrepreneurship earlier, as my interest lay only in research and publications.

Alex: I used to work for Zoho, Chennai, and my work was mainly focussed on the product management space. Zoho was started in 1996 and they had a mission to bring some amazing products out of India. Through my job, I understood product management and I further got into scaling products globally. I have scaled products in different regions and markets such as Latin America, Europe and the Asia-Pacific region.

What is the story behind tinto rang?

Fathima: When we were thinking about building products from my research, we thought about a few things that could be converted to or developed as products. So we looked at a prebiotic drug for diabetes management.

Alternatively, I had some experience with natural dyes during my PhD. We extracted a lot of natural dyes that could be used by the local community for mat weaving. We identified one such natural dye that could bind to DNA and I started working on tinto rang's development at IISc. ("Tinto" means red in Portuguese and "rang" in Hindi is colour.)

It took me about a year to optimise it to a certain extent and another year to craft, formulate and build it to what it is now. Then I had challenges purifying and characterising the molecule. I went onto characterise its DNA-binding ability, staining and fluorescent properties. Luckily, the experiments took direction in a good way. I'm fortunate that every experiment worked.

How would you evaluate the market potential of your product?

Alex: India doesn't produce nucleic acid stains. We import them at 30% duty. The impression that most people around the world have is that Indians produce cheap products – we have a reputation for copying something and bringing it out cheaper. Our product [tinto rang] is premium and not cheap. We've priced it at $3 more than SYBR Safe [another nucleic acid dye]. At the same time, we are not keeping the product too expensive as we don't want to defeat the sales of the product.

In India, we are doing a replacement offer – we ask them [customers] to pay a similar price to the existing dye for six months and, if they like it, we plan to charge them at normal price. This will give them enough time to realise how much they are saving in terms of the procedures that come with the use of EtBr, such as decontamination and biohazard disposal. This is the advantage we are trying to pass on.

We were targeting biopharmaceutical companies initially. To our surprise, a lot of seed companies were interested. They have signed up for field trials.

Fathima: Most scientists are of the opinion that EtBr is used in very small quantities and may not have a big market. Only after receiving customer feedback did we realise the volume of usage. With the data we collected, we realised that it is a 50-billion-dollar market. In research, we sometimes don't realise the impact a small chemical can have in terms of business. The consumption [of EtBr] is similar to sugar and salt – though consumed daily in small quantities, its absence cannot be ignored.

The consumption of ethidium bromide is similar to sugar and salt – though consumed daily in small quantities, its absence cannot be ignored

Tinto rang packed in a biodegradable box (Photo: Rohini Krishnamurthy)

What about tinto rang's safety?

Alex: We have a CE [Conformité Européenne] certification which is a compliance certification for food grade. CE is a worldwide approved marking, accepted in most of the countries. In the US, they insist more on FDA certification. Our claim to safety is that it is [derived] from a food additive that we are [already] consuming.

Fathima: In addition to that, we have performed certain laboratory studies that prove tinto rang to be non-toxic. The simplest test was observing contamination (growth of microorganisms) in our sample stocks. In our imaging studies, we have tried culturing cells with the dye – it usually doesn't have implications [the product didn't have toxic effects on the cultured cells]. We will now be moving to FDA tests. Since we are competing with the giants, we are getting all possible certifications. We are leaving no stone unturned in this matter.

Could you tell us about SID and how it helped shape your business?

Alex: We had support from SID. We knew getting financial support to set up a lab is not very difficult but getting the expertise that IISc has been offering is difficult. They gave us a special innovation grant from which the company was created. We are very thankful to them. Earlier, I used to think SID is pretty slow but the good thing is that there's absolutely no bureaucracy and hierarchy here. What takes a longer time in other incubators takes a shorter time at IISc. We will not be called a start-up after 7 years [of incubation] but I still intend to run a commercial space on campus till they decide to kick us out.

Fathima: SID is not a proactive incubator like the others, but they help us whenever there is a need and solve our problems immediately!

Alex: That was a year back; now they are swinging into action. SID is like this no-nonsense workplace where nobody is standing in your way.

Fathima: We met a lot of other innovators and they all had tonnes of complaints about policies followed at their incubators including entry and exit policies. When we are fighting some greater challenge, the last thing we want is a gatekeeper. Apart from professional help, IISc has nurtured us. I haven't seen this in the several incubators we visited. Nothing comes close to what IISc has to offer.

Also, Prof Savithri HS from the Biochemistry department helped us understand problems that start-ups could have and helped us navigate situations. Not just that – she's been a huge moral support. Just "help" is an understatement. She encouraged us by saying that this is a good way to show the world that we are also capable of coming up with innovations and not just copying something.

What are the hurdles you had to face as an entrepreneur?

Alex: There is a huge stigma in society presently. My parents couldn't understand why I quit a well-paid job. Everybody thinks I'm selling "podi" ("podi" is powder in Tamil). There is some uncertainty in the start-up world. Our parents had reservations in the beginning.

Fathima: My challenges were far more magnified because I am a single mother of two kids and my parents thought I was getting into something I had no idea about. They said it's better that I play it safe by getting a job, even if I don't make it big in life. Overcoming the stigma and making them understand was the greatest challenge. It took a toll on us initially – but the manner in which we were

progressing and heading forward helped us overcome these personal battles. I think what I've realised from this is that keeping myself busy helped me overlook a lot of unwanted things.

Alex: The second [hurdle] was the system itself. Companies in countries like the US, Israel, Singapore and other locations are receiving huge support whereas we have a long way to go. Most grants that fund start-ups today are still funding "projects" and not "products" because I think they themselves don't realise the market potential of products.

Most grants that fund start-ups today are still funding "projects" and not "products" because I think they themselves don't realise the market potential of products

Fathima: They are still funding highly technical ego-boosting projects which don't have any immediate impact or are of no immediate business value. That was a very demotivating factor when we started off fighting this bureaucratic system. So we started to think about which battle was worth fighting: was it the system or the problem we have at hand? We chose to fight the battle that gave us more purpose and meaning.

Tinto rang is expected to come out soon in the market. Do you have other products in the pipeline?

Alex: Yes, our next product is called Ano cell stains. Cell stains are rare and not manufactured in India. Such stains currently available in the market have a photostability [resistance to degradation in presence of light] of 40 seconds. To maintain it, an anti-fade agent is required, which is again expensive. Ano cell stains have a photostability of 30 minutes. However, this product hasn't yet been released commercially because we did not want to steal tinto rang's thunder. But we've had interactions with some of the customers to know its prospects. They showed interest and asked if they could include it in their catalogue before the product is released. We are also looking at bioimaging where fluorophores can help biologists view biological systems. Our focus is also to come up with fluorophores in the Infrared (IR) region. Thermo Fisher and other companies are coming up with IR-based devices which are cheaper in comparison to optical lasers. Currently, most fluorophores in the market don't fall in the IR range.

How do you see yourself five years from now?

Fathima: We are running field trials [for tinto rang] currently. The reason is that our product could work differently in different environments. So we are collecting feedback from our customers so that we can craft the product well. IISc has mostly new generation devices, which is not the case everywhere. A few start-ups and private colleges use diverse devices – like older versions of transilluminators and some indigenously developed devices. So we are now focussing on collecting information to check for device compatibility and reproducibility.

Alex: We are looking at global expansion six months down the line. We should be in the market by end of 2018 commercially. We are first targeting the US and Europe, after which we plan to expand to Singapore and South Korea.

Expansion in Europe requires start-ups to pay 30-40 percent tax. But the Netherlands Foreign Investment Agency in Amsterdam has something called Innovation Box that is letting us set up business by paying them 5 percent tax for five years. Given the European tax norms which are upwards of 30 percent, it is a very useful programme for any start-up. It seems like it's a good place for innovative start-ups as we don't have to deal with taxes & other complications.

Fathima, what have you learned from your experience as a researcher and now as an entrepreneur?

From my journey, I have realised that solutions to problems are simple. However great or complicated the technology is, until it is simplified, the solution has no business value as nobody is going to adopt it. We could change our focus and look around for simple solutions to problems because as scientists and researchers we have a tendency to solve complicated problems. I think it is that challenge that boosts the ego of every scientist. This is my valuable realisation through this journey that most of the scientists fail to see. Simplifying solutions can make science more application oriented.

Photo courtesy: Christine Brown

Structures in turbulence: An interview with Garry Brown

Nithyanand Rao

From left to right: Anatol Roshko, Garry Brown, Hans Liepmann and Roddam Narasimha

***Garry Brown is professor emeritus at the Department of Mechanical and Aerospace Engineering, Princeton University. He is a distinguished fluid dynamicist, well-known for his work with Anatol Roshko where they found unexpected order within turbulent flow. He was at IISc in late 2017, teaching a course on shear turbulence with his friend Roddam Narasimha. Excerpts from an interview with* Connect.**

In your 1974 paper with Anatol Roshko [the former Theodore von Kármán Professor of Aeronautics, Emeritus, at Caltech, who passed away in January 2017], you observed order within turbulence – "coherent structures" at the interface between two gases, one high speed and the other low speed, flowing past each other. What was the context for this work?

The purpose of the work was not to examine structure or any of the questions that the results finally seemed to address. The original motivation for the work was to study the behaviour of separated flow in compressible flow, where you have speeds in excess of that of sound. The temperature is lower and the density correspondingly higher for one stream [of fluid] than it is for fluid on the other side near the base of the body, where the temperature is higher and the density lower. The abstraction from that technologically important problem was a well-posed scientific one. And that's where Anatol Roshko was particularly capable. He was able to make a connection between something that was technologically going to be important and translate it into something that was scientifically well-posed.

Did it also have something to do with the Apollo mission?

Well, yes. Roshko was prominent also as a consultant to industry. One of the questions related to the Apollo mission that needed to be addressed was if there was leak of oxygen from the capsule and hydrogen fuel from the base – and the hydrogen, because of its low density, propagated up the side of the Saturn V rocket – what's the probability that they would be in a stoichiometric mixture that would be potentially flammable when they reached the same location? He didn't know the answer but thought that it depended upon the ratio of their densities and their respective velocities. So the motivation was to do an experiment with different gases and with different densities.

Which gases did you use?

We used as principal gases nitrogen and helium. I started out with two streams of nitrogen because helium was so expensive. I designed a facility that would operate for three seconds at pressures up to ten atmospheres so that we could make measurements and take photographs of the flow field between these two streams at high densities (Reynolds number). We were astonished when we saw the photographs for the first time.

These were high-speed photographs based on a point-spark source. We used a large concave mirror, and the spark source was at the focus of the mirror, so we produced a parallel beam of light. And then variations in refractive index arising from small differences in gas concentrations or temperature would refract the light and that produced what's called a shadowgraph. It enabled the turbulent fluid to be readily distinguished from non-turbulent fluid because it had small fluctuations in refractive index.

We saw these pictures, and I was tremendously troubled by them because I saw structure and order that I didn't expect to see. I spent two months trying to get rid of it. And I couldn't get rid of it. It seemed to be an intrinsic part of it.

At the time, the classical picture was that once it [the flow] became turbulent, you lost all structure and that it would be entirely statistical, there would be no evidence of any order. Well, that proved not to be true.

Photo: Nithyanand Rao

You're currently teaching a course here at IISc with Roddam Narasimha. When did you first meet him and Satish Dhawan?

I think I met Prof Dhawan before I met Prof Narasimha. I was a research fellow then, and I had no idea of the eminent status of Prof Dhawan who was at the time the Director of IISc. But he came on a study leave to Caltech and taught a course. I was very fond of Satish – he was very open to any kind of discussion. We used to chat over lunch. It was on one such occasion that he received this remarkable letter from Prime Minister Indira Gandhi inviting him to head the Indian Space Research Organization [ISRO].

He was the one who mentioned Narasimha. I was back in Australia – Adelaide – after I left Caltech. I came to Bangalore to say hello to Prof Dhawan and at the same time to talk with Prof Narasimha. We had a lot in common and I admired his work very much. And we have been close colleagues ever since, from the mid-1970s.

What were your impressions of Dhawan?

I think Satish Dhawan would have agreed that his talents were broader and different from those of the greatest scientists. He had wonderful leadership qualities – a combination of transparent integrity and a willingness to be very successful through the success of others. That's frequently not a characteristic of the greatest scientists – they often don't see themselves as being successful through the lives of others. The best teachers do, but the others perhaps don't. So I would put Satish Dhawan as one of those uniquely capable people who could lead others. And it's clear that his record at IISc and ISRO is a true testament to that ability.

You've been a Rhodes scholar at Oxford, you've been at Caltech, Princeton, and you've served in universities and other research organisations in Australia. What would you say you've learned from having studied or worked at these different places?

One of the things I've come to appreciate is how important it is to define well the mission at the top. What are we actually there to do? At Princeton University, the mission was definitely not to educate the next generation of faculty members. It was to develop the leaders for the next generation of people in all walks of life. It was to try and recognise that the students are multi-talented in many cases, very capable. But their potential contribution to the country could be very broad and needed to be maximised. They needed to be given the opportunity to develop confidence, competence and creativity – the three Cs that I used to quote.

The strategic purpose of Princeton University was changed, on the 175th anniversary of Princeton, from the Woodrow Wilson quotation which had been developed in the 1920s. Woodrow Wilson's statement was "Princeton in the Nation's Service". That statement was widened by Toni Morrison, the Nobel Prize winner [in Literature], who was the chair of the committee, to "Princeton in the Nation's Service and In the Service of All Nations". Once you say that, teaching becomes central. The faculty are thought of as "teacher-scholars". Correspondingly, the metrics by which their salaries are determined are three: teaching, determined by feedback from the students; research; and scholarly citizenship, which has to do with participation in national committees, consulting for important industries and participation on professional scientific bodies.

At Caltech too, teaching was central. [Richard] Feynman even argued that there should not be institutes of advanced study for special scientists because he always felt that teaching made sure that people reviewed the broader areas of their knowledge continuously. [Hans] Liepmann, who became the director of GALCIT [Graduate Aerospace Laboratories of the California Institute of Technology], was very much of this view too. In that tradition, the motto for Caltech is the passing of the torch from one generation to another.

To P or Not to P:

The Search for Significance

The null hypothesis is never proved or established, but is possibly disproved.

- Ronald A Fisher

Is the P value as reliable as we believe? This article examines the meaning and limitations of this ubiquitous measure of significance

Statistics is a versatile field that emerged from 17th century political science and state governance. In time it evolved into a vast and sophisticated discipline and yet has remained a powerful, widely-used instrument to analyse, summarise and communicate key scientific findings from numerous other academic spheres.

Statistical tools have become indispensible to research, and with good reason. When intangible or abstract associations can be structured into numerical or mathematical descriptions, it allows reproducibility, the central tenet of research.

The simple beauty of the quantitative approach shines through in cases when intuition or common sense may mislead us. Sandeep Pulla, a PhD student studying forest dynamics at IISc, uses the classic example of the birthday problem to illustrate this: what are the odds of two people in a group of 23 sharing a birthday? Answer: a 50-50 chance. Based on everyday logic, this seems absurdly high, but combinatorics doesn't lie.

Statistics is especially critical when we investigate complex phenomena because rarely can we bring all sources of variation under control. As we gather various observations, it becomes important to clarify to what degree our numerical descriptions reflect the real world.

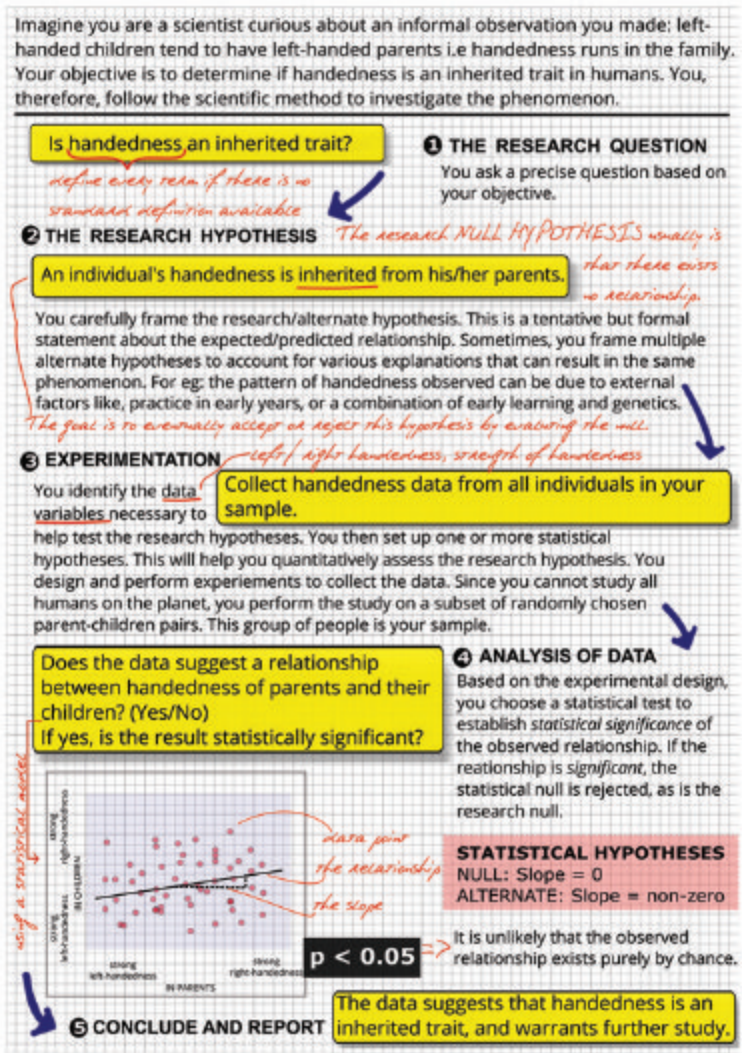


Illustration: Upasana Sarraju

An overview of the scientific method as used in a hypothetical research process

Fisher did not intend for the P value to be a definitive measure of data reliability. Instead, he devised it to judge if a scenario was worth investigating, worth a second look. The lower the P value, the less likely that the observed result was found by chance in the absence of a true effect.

Convention dictates that a threshold value of P is chosen, below which the null hypothesis may be rejected and the results considered "significant". This threshold value of P is widely accepted to be 0.05.

Fisher's comments on the P value in his seminal work *Statistical Methods for Research Workers*, published in 1925, reveal the elusive nature of this threshold: *"The value for which P =.05, or 1 in 20, is 1.96 or nearly 2 ; it is convenient to take this point as a limit in judging whether a deviation is to be considered significant or not . . . Small effects would still escape notice if the data were insufficiently numerous to bring them out, but no lowering of the standard of significance would meet this difficulty."*

The P value is not an objective statement of statistical significance, and certainly not of biological (or real world) significance, argues Kavita Isvaran, an assistant professor at the Centre for Ecological Sciences.

P value: the gold standard?

The P value appears to provide answers to the questions "Is the pattern observed in the study real or is it part of natural chance variation?" and "How reliable is this result?"

The concept of the P value – or calculated probability – was introduced by Ronald A Fisher, a pioneer in statistics and biology, as an informal index of discrepancy between the data and the null hypothesis. Fisher was considered a genius and often an outsider, who formed lifelong feuds and braved incredible hardships. He invented many important statistical techniques and formalised several others, which remain in use even today. He also travelled widely, forming close associations with great minds of the day, including PC Mahalanobis and RC Bose of the Indian Statistical Institute.

She points out that the dichotomy dictated by P value significance is a false one. "A P value of even 0.045 can make us happy and encourage us to build large narratives while P=0.055 can make us unhappy with the 'weak trend' and give up on it, when both those values must be treated with similar uncertainty."

Perhaps the most common misconception is to consider the P value as the probability that the null hypothesis is true. The common perspective to significance is deeply entrenched today. Pulla clarifies, "Statistics is useful, but aiming for significance is what leads to problems because then we enter the world of human cognitive biases, and that is a grey area of seeing what we want to see in our data or as patterns around us, and misunderstanding statistical techniques."

The slippery nature of the P value has been largely overlooked by the research community contributing to the reproducibility crisis in science. A survey by *Nature* shows that more than 70percent of researchers were unable to reproduce another scientist's experiments and were often unable to reproduce their own experiments. Much time and resources have thus been exhausted in pursuing false leads.

What is the bottomline, then?

"In real world situations, the statistical null hypothesis (for example, that two means are exactly the same or that a relationship is exactly equal to zero) is rarely true. Our task is therefore to estimate the thing we are interested in with high precision," says Isvaran. She argues that if, instead, we focus on P values and whether an effect is present or not, we may ignore an important biological effect just because we get a P value that falls on the wrong side of our cut-off. The low precision, she says, could result from a small sample size. And conversely, with large enough sample sizes, we run the risk of getting small P values and establishing the statistical significance of trivial effects.

The result of mishandling statistics is just that – the outcome of unintentional laxity or ignorance. Persistent misguided application of the P value has led to what is now infamous as P-hacking, also called data dredging, significance questing, selective inference, double-dipping and researcher degrees of freedom.

Several months or years pass before faulty results are identified, often due to a general culture of uncritical approaches to handling data. An example of brazen ambition to yield results that have just the right value of significance is that of Diederik Stapel, a Dutch social psychologist. While his is a rare case of intentional misconduct, it highlights the acceptance of significant results at face value. Stapel knew that the effect he was looking for had to be small in order to be believable; psychology experiments rarely yield significant results. He proceeded to work backwards and generate the data that would yield to the required distributions.

Armed with data, planned and unplanned, a researcher would explore what was at hand

The reality of our times is that most scientists follow ethical practices and contribute to advancements in small increments.

The problem is actually caused by taking decisions freely without accounting for them: conducting analyses midway through experiments to evaluate their potential success, recording multiple response variables not part of the original experimental design and incorporating them at a later stage, deciding whether to include or drop outliers after analysis, modifying treatment groups post-analysis, including or excluding covariates post-analysis, and terminating data exploration if an analysis yields a significant P value. Isvaran points out that such missteps are easy to take. "If I observe new and seemingly important features while I'm collecting planned data, I would, of course, record these observations." Armed with data, planned and unplanned, a researcher would explore what was at hand. "However, it is well known that when one explores patterns in the data, one runs the risk of finding spurious relationships. So it is important to separate careful and targeted analyses from when one explores a large number of possible patterns," she says.

According to Pulla, an interesting result in a field of scientific inquiry is one that is novel, unexpected, contrary to the current state of the field and of course, and therefore, likely to be accepted for publication in high-impact journals. These very characteristics necessitate further scrutiny of such results. However, it is often the case that fantastic findings are accepted and developed upon, sooner than replication studies can verify them. Pulla points out that the editors and reviewers of scientific journals may themselves not be fully aware of the nuances of statistical tests.

So how common is bias from P-hacking?

A study found that while P-hacking is widespread, it does not drastically alter conclusions drawn from meta-analyses, analyses that combine data from several studies.

The use of the term P-hacking, and its synonyms, affects how the issue is perceived in the scientific world. These terms suggest that researchers persistently explore their data until the desired result is observable and significant. However there is a glitch in the critique against P-hacking: terms like 'data fishing' suggest that those who use P values unwisely are, in some sense, mindful cheats. And when researchers believe they lack the intent to manipulate data, they may forgo necessary caution when preparing for and performing data analysis.

Photo courtesy: RA Fisher Digital Archive, University of Adelaide

RA Fisher with PC Mahalanobis and his wife Nirmal Kumari Mahalanobis in 1946

To better describe the issue, the term *garden of forking paths* was introduced because it conveys the idea that the paths, or choices, are all out there. The chosen method of analysis may be reasonable given the data and assumptions, but had the data been different, there may be other equally reasonable analyses, which may alter the conclusions. But unfortunately, very little information about these behind-the-scenes decisions is evident in the reported results.

Particle physics research has attempted to address the issues associated with the P value by using a much more stringent standard than those used in other sciences. The groundbreaking discovery of the Higgs boson adhered to this standard as well. However this threshold is also just a consequence of statistical anomalies being paraded as new discoveries using a formerly acceptable standard.

In today's competitive world, there is more pressure today than ever before on young researchers to find novel and broad questions to pursue. In the journey to find one's place in the prolific world of research, one can give in to the tendency to look for patterns, meet the impact-factor yardsticks for professional excellence, imbibe widely echoed sentiments, play the media game.

To prevent P-hacking, Isvaran believes that one must remind oneself about the original motivation and study design. "Let me clearly separate out the exciting unplanned exploratory findings from the planned confirmatory tests that I designed the study for." There is no reason why fascinating post facto findings should not be reported (so long as they are clearly labelled as such), along with the findings from the original design.

Another measure against losing one's way in the garden of forking paths is declaring the research plan in advance. Pre-registration of studies in hubs such as Open Science Framework publicly specify the study in such a way that all its aspects are accounted for well before the project is underway. This eliminates hidden changes being made to the original approach.

Another measure against losing one's way in the garden of forking paths is declaring the research plan in advance

"You want to be aware that there are alternate explanations for any correlation, and give them equal weightage in your thinking." says Pulla. "The simulation approach is powerful, especially when using large datasets and advanced techniques. It is worth applying your models to datasets for which you already know the answers. It makes you more aware of the caveats in the method you have used, and more tentative in your approach to interpretation."

It is also the responsibility of mentors to make students aware of cognitive biases, pitfalls of a particular decision, and to emphasise the importance of content over publication in a well-known journal, says Isvaran. The onus is on those more experienced to share their knowledge. But each of us must work toward a better understanding of all our scientific tools. When the integrity of your work is in question, ignorance is culpability.

Upasana studies genetic diversity in Asian elephants at the Centre for Ecological Sciences

The marriage that couldn't solve Morris Travers' troubles in Bangalore

Photos courtesy: APC, IISc

Morris Travers met Dorothy Gray while on leave in England in 1910, and proposed to her immediately

The following piece is an edited excerpt from the unpublished autobiography of Robert MW Travers, the son of Morris Travers, IISc's first Director.

Locked in a tussle with JN Tata's sons over his plans for IISc before he travelled to England on leave in 1910, Morris Travers sensed that having a wife would enable him to make more social contacts in India, and had decided to return a married man. While in England, Travers was introduced to Dorothy Gray, a girl from a wealthy family. He proposed immediately, and the very next day, she accepted. In just a few weeks, they were wed.

The couple had planned a country honeymoon of two or three weeks, but on the third day my father received an urgent message from India saying that powerful political forces were at work to remove him from his job. The honeymoon came to an abrupt end. The bride's beautiful trousseau was hastily crammed into suitcases. The hotel rapidly harnessed a horse to the guest shay* and bundled the couple and their luggage into a train which would take them back to London. They arranged accommodation on the first mail boat to Bombay. In those days, affluent passengers to India never boarded the boat at the London Docks but took the train across France and Italy, boarding the ship at Brindisi and cutting two days off the trip. The boat they planned to board had already left London at the time of booking, but they were able to catch it by taking the overland route.

The dash across the European continent occupied two days and nights in the train. Each must have tried to appear cheerful but each must have known the deep anxiety the other experienced. Then they spent ten days on a boat, isolated from all news that might have told them more about the crisis that had precipitated the race to India. The boat was hot. Those able to make advance reservations had taken all the cabins on the shady side of the ship, so that all that were left at the last minute were the star-board cabins into which the tropical sun blazed all day long. I can only judge from how I saw my parents react to stress in later years, how they must have reacted to each other on this voyage. I can imagine them being very quiet, talking little, with my mother always playing a supportive role but in a very subdued way.

Photo courtesy: APC, IISc

Dorothy Gray Travers with their first child, in India

One can hardly believe that it was just luck which led my father to pick a wife who had all of the qualities he lacked. Undoubtedly, he saw in her the characteristics that made a wife acceptable. She was an entertaining conversationalist. She could talk about music and literature. She spoke fluent French and German, which gave her an entrée into scientific society. She had a marvelous sense of humor and could tell a story in the most refreshing way. It was almost as if she were on the stage. She could do this partly because she had a great capacity to empathize with others and partly because she had natural talent for acting. Indeed, in another age she might have become a great actress.

This couple who embarked on adventure together could not have been more differently endowed. His magnificent, cold, logical intellect contrasted with her intuitive, warm, and artistic capabilities. He was well-read in the sciences but had little use for great literature, but she felt that a day without deriving inspiration from a poem or from some passage of literature was a day that was wanting. He could talk well but was a poor listener, but she could both talk and listen.

Often, strange circumstances draw couples together, and nothing strengthened the bond between my parents more than the fact that Father was in deep political trouble. Mother always had feelings for anyone in trouble. In Father's autobiography, written 40 years later, one of the few human touches is found in his statement: "I went and told D all about my problems." He had probably never had a confidante, and the relationship not only enriched his life, but made his problems endurable.

The couple also made an effort to present an air of confidence to the social world in which they mixed. They moved into the new residence provided by the Institute and began to give magnificent receptions. It was not uncommon for them to invite 100 or more to an evening reception on the grounds where a military band would entertain the guests, and the native cooks who were virtuosos in their art provided the finest food. Mother blossomed into the role of hostess. Unfortunately, her appearance on the Indian scene was just too late to reverse the tide of conflict within the Institute's administration.

My sister and I arrived in the midst of this period of turmoil and torment. Hardly surprising it is that in Father's autobiography he mentions the arrival of his daughter in just a single paragraph. He simply did not mention my arrival.

Although the crisis in India was a product of Indian politics, it was one which a person with my father's disposition did not easily handle. He reacted to such crises with anger rather than with political shrewdness.

When the honeymoon was cut short by a cable from India, Father must have realized much had gone wrong in Bangalore during his absence. What had happened was that some members of the Council had taken the opportunity provided by his absence to take steps to remove him from his position.

The strategy of the Council, designed to remove the Director, was a product of the times in India. Bribery and corruption permeated the system. Perhaps even a majority of prosperous citizens were guilty of participating in the bribery system. A charge of financial corruption must have seemed to the Council a sure way of getting rid of the Director. What they did not realize was that the Victorian gentleman might be a man of many vices, but the Council had picked one vice to which he was not prone. The Council did not understand the English culture, just as the Director did not understand the Indian culture. To charge the Director with financial corruption was as ridiculous as charging the Pope with making advances, in public, to young women. The Council and the Director belonged to two different worlds and neither understood the world of the other.

Father was furious that anyone should doubt his integrity. If his relationship to the Council had been cold up to this point, it now turned white-hot. The Court held an inquiry which proved the charges unfounded, but the Court could settle only the issues brought before it and could not resolve the deep incompatibility of the Council and the Institute's Director.

Although I have told this story in few words, the events dragged out over a period of several years. In their home life, Morris and Dorothy Travers were drawn closely together sharing their misery. In his public life, my father was able to proceed with work on the development of the buildings of the Institute. Most of the essential structures emerged out of the jungle. Students slowly filled the laboratories and classrooms, and several of these early students went on to have distinguished careers. Whatever Father could not do, he was materially successful in accomplishing his goal of building the kind of institute he wanted.

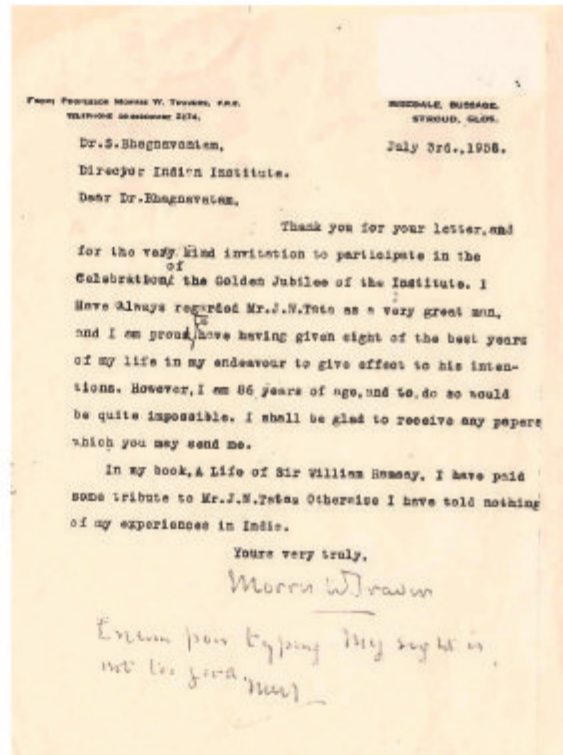
After the attempt to take Father to Court had failed to result in his removal, a period of cold war lasting several years resulted. Members of the Council who had opposed the policies of the Director must have been somewhat chagrined that the Institute was becoming a success. The Institute was able to attract many students of high intellectual caliber and also some who were not so able. The less able students

became an issue of dispute between the Council and the Director. The Council believed the students were not receiving a fair shake. The Director called for the dismissal of some of the students unable to meet the academic standards. Eventually the Director settled the matter in a politically shrewd manner. He eliminated the students from the program but gave them positions as laboratory assistants in which they could behave competently. The issue became just one more example of tension and bickering within the Institute.

Morris Travers sought solace in the only way in which he knew. He began to undertake work in the laboratory, though I have often wondered how a man running a large institution could find time to do so. However, he did have competent junior members of his staff capable of carrying on the daily functions. Escape into the laboratory gave him the feeling of being in a place where he was sure of his ability to handle all contingencies. Perhaps he may even have had dreams of recapturing some of his prestige as a laboratory scientist, a prestige which in time had slowly eroded in the memories of his colleagues in the scientific world. The new scientific work he did manage to undertake was sound, but it had none of the brilliance of his earlier efforts. Its main value to him was to enable him to withdraw from the strains of administrative life and the torture of the conflict between himself and the Council, which also needed a period of respite from deep and emotion-filled conflict.

In the year 1913, the Council began to search for ways of coming to terms with the problem. They approached the Director concerning the conditions under which he would leave the Directorship. The terms could have been arrived at easily and without debate, but they involved much bickering. He had received his initial appointment in 1907 for a period of ten years, but the last two years were to be a paid vacation, and he was to receive a pension for life. By simply extending his terminal vacation, the Council was able to ensure his departure. After considerable argument, this is what the Council and the Director eventually agreed upon as a solution to their differences. In the summer of 1914, Morris Travers and family returned to England.

Two postscripts must be added to this account of Morris Travers' Indian venture. The first postscript is that in 1957, the registrar of the Institute sent Father a set of pictures of the Institute. One of these was a picture of a new and magnificent building. Underneath the picture were the words "Economics and Social Science Building". The picture must have been a terrible blow to Father, for it seemed to him a monument to the opposing side's victory and his own defeat.



Dr.S.Bhagavantam, July 3rd.,1958.
Director Indian Institute.

Dear Dr.Bhagavatam,

Thank you for your letter, and for the very kind invitation to participate in the Celebrations of the Golden Jubilee of the Institute. I have always regarded Mr.J.N.Tata as a very great man, and I am proud to have having given eight of the best years of my life in my endeavour to give effect to his intentions. However, I am 86 years of age, and to do so would be quite impossible. I shall be glad to receive any papers which you may send me.

In my book, A Life of Sir William Ramsay, I have paid some tribute to Mr.J.N.Tata Otherwise I have told nothing of my experiences in India.

Yours very truly,

Morris Travers

Excuse poor typing. My sight is not too good. Mt

Photo courtesy: APC, IISc

Letter from Morris Travers in 1958 to IISc's Director S Bhagavantam. The handwritten postscript appears to read: "Excuse poor typing. My eyesight is not too good."

A second postscript is that the bitterness of the experience left a permanent scar on his life. He believed that he had sacrificed a scientific career by going to India and by turning to administration. He believed he had been succesful but that his success as an administrator had not been recognized. India left him with a bitter taste that lasted the remaining fifty years of his life. Even worse, he became highly sensitive to what others might say about his success or failure in India. There were times when he had deep suspicions that some people had a one-sided view of what had happened to him in India and that it was not the side he would choose for them. He collected newspaper cuttings and other materials about the Institute to search for recognition of his contribution. He wrote a long autobiography, nearly half of which covered the problems he encountered in India, but his time there had occupied less than one-tenth of his life. Despite surface confidence in his success at the Institute, he had a haunting fear that he might not have been entirely right in India, and it was that fear that he never learned to live with or accept.

*chaise – a light horse-drawn carriage

How IISc found a home in Bangalore

Karthik Ramaswamy

Back when the plan to set up the Institute was being chalked out, the southern city was hardly the most obvious choice to house it

"Bangalore is already the Science Capital, start-up Capital and Technology Capital of the country," Biocon founder Kiran Majumdar Shaw tweeted recently in support of a demand to make Bangalore India's second capital. While there may be many aspirants for a new supplementary capital city, few would quibble with Shaw over her description of Bangalore, home to several educational and research institutions, public sector R&D industries, IT and biotech companies, and technology-related start-ups. Over the decades, the emergence of the city as a hub of science and technology in India has resulted from a confluence of factors. Chief among them is the presence of IISc, established here more than a hundred years ago.

In the late 1800s, when IISc was still a gleam in the eyes of its founder Jamsetji Nusserwanji Tata, Bangalore was an unlikely candidate to house the Institute. Situated on the Deccan Plateau in a semi-arid, hilly terrain, dotted with dry deciduous forests and thorny scrubs, Bangalore had not fully recovered from the ravages of the Anglo-Mysore wars. Though the Cantonment in the city was mushrooming (the city was a popular destination for the British soldiers because its climate allowed them to play cricket and polo for most of the year), the more crowded "pete" – the settlement of the local people – still experienced famines with disturbing regularity, and was also the epicentre of the outbreak of a plague epidemic that shook the city in 1898.

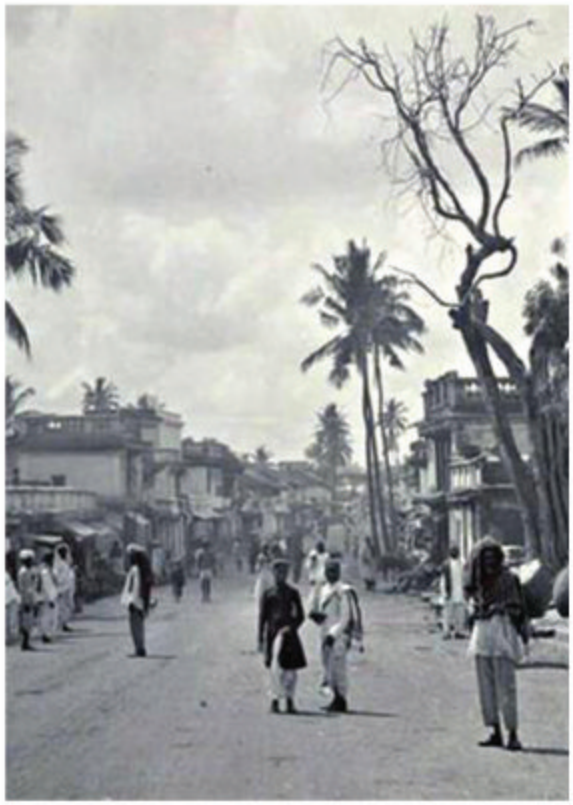


Photo credit: British Library/Creative Commons Licence/Wikimedia Commons

Bangalore pete in the 1890s

So how did Bangalore, then a small city, grappling with public health issues and not much of an academic tradition to speak of, become home to IISc, beating more established favourites? The answer to this question is closely intertwined with the story of how IISc came to be.

The answer to the question of how IISc was established in Bangalore is closely intertwined with how it came to be

The story begins with Tata, an enormously successful industrialist with strong philanthropic instincts. He was keen to use his vast financial resources for a cause that he believed would bring about social transformation, rather than partake in what he considered to be "patchwork philanthropy." To fulfil his ambition, Tata – a man of ideas as much as a man of business – considered the possibility of contributing to India's higher education. His plans crystallised when he decided to set up a university of higher learning in 1889, inspired by the words of Lord Reay, the Chancellor of Bombay University (a position he held by virtue of being the Governor of Bombay). In his Convocation address, Reay lamented the state of Indian universities – which in those days were merely examination bodies – and urged the "wisest men in England and India" to establish "real universities" instead.

Photo credit: Edwin Arthus Ward/Creative Commons Licence/Wikimedia

A painting of JN Tata

But the process of building a university from scratch in a country with limited resources and no research infrastructure was going to be long and arduous. Tata embarked on his project earnestly only in 1896 when he called upon Burjorji Padshah, an educationist whom Tata had mentored as a young man, to oversee the implementation of his vision. As a first step, he sent Padshah on an 18-month trip to study European universities. Upon his return in 1898, Tata set up a 23-member Provisional Committee (of which Tata too was a member) headed by Padshah to come up with a detailed scheme for his grand project.

The committee began its work by seeking the views of educationists and thinkers across the country about Tata's plan – which had been made public by then – including on where they thought such a university should be located. A majority of the 76 people consulted favoured Bombay (Mumbai) because of its "industrial life, wealth, and civic importance." Bombay was also Tata's

hometown. Before setting up the Provisional Committee, he had considered the possibility of converting his alma mater Elphinstone College, or perhaps the existing Bombay University, into a teaching university. He gave up the idea quickly when he realised that such a move would defeat the purpose of what he set out to do. Other suggestions made to the committee for the potential location of the university – tentatively called *The Imperial University of India* – included: Calcutta (Kolkata), Poona (Pune), Coonoor, Nainital, Allahabad, Bangalore, Roorkee and a few other smaller cities.

A majority of the 76 people consulted favoured Bombay because of its "industrial life, wealth, and civic importance." Bombay was also Tata's hometown

Photo credit: Creative Commons Licence/Wikimedia

Statue of Seshadri Iyer in Cubbon Park, Bangalore

Following several weeks of consultations with experts on the question of the proposed university's location and other issues, including its nature and finances, the Provisional Committee prepared a preliminary scheme. The scheme was presented to Lord Curzon by a deputation led by Tata on 31 December 1898, the day after he arrived in Bombay to take over as the Viceroy of India,. Curzon had several questions for his guests and did not seem particularly enthusiastic about the plan. But Tata was not entirely disheartened by Curzon's response.

In early 1899, Tata undertook a tour of South India. His last stop was Bangalore, where he met the Dewan of the Mysore State, Seshadri Iyer. The Dewan served as the advisor to the Regent Queen Vani Vilas Sannidhana, who ruled the Kingdom on behalf of her son, Krishnarajendra Wadiyar, coronated in 1895 when he was only 10 years old. (Years later, in 1911, during the laying of the foundation stone of the Institute, the Maharaja recounted the foresight and generosity of his mother in setting up the Institute.) The Dewan was an old friend of Tata – he had helped Tata develop a silk farm in the outskirts of Bangalore. Iyer wanted the State of Mysore to take the lead in using science and technology to improve the lives of its people. Back in 1895, he had even written to John Cook, the Principal of Central College in Bangalore, saying that Mysore would be happy to support a university in Bangalore if such an idea took root, a promise he reiterated to Tata four years later. But this time his proposal was more concrete: Mysore State would provide about 300 acres of land, and also contribute towards the cost of building the university, provided it was in Bangalore. It was an offer that Tata would find hard to resist.

The Dewan's proposition, now part of the revised scheme submitted by the Provisional Committee to the Government of India, was discussed at length during the Simla Conference in October 1899, a meeting that was organised by the Government to take Tata's initiative forward. During the conference, attended by Tata, Padshah and Curzon among others, the Government approved the Provisional Committee's scheme in principle and suggested that the new university should be called the *Indian University of Research*. And as for its location, it was a two-horse race between Bombay and Bangalore.

Bombay was the sentimental favourite in spite of the Dewan's offer. "As is natural most members of the Provisional Committee of the University are in favour of Bombay," the proceedings of the conference noted. The attendees also seemed to be swayed by public opinion and the vociferous lobbying by Bombay's press. "The public opinion of Bombay as expressed in the best English and Vernacular papers like the *Times of India*, *Bombay Gazette*, *Indu Prakash*, *Gujrati*, *Indian Spectator*, is unanimously in favour of Bombay," it added.

But Bombay was far from ideal for a large university – it was a crowded island where finding land for such a massive venture was impossible. And its high humidity made it unsuitable for books and scientific apparatus.

Bangalore's climate, on the other hand, was, "second only in attractiveness to that of the Nilgiri Hills," the proceedings said. And the expression of support – of both land and money – by the Mysore Durbar was taken seriously. By the end of the conference, Bangalore was looked upon more favourably.

By the end of the conference, Bangalore was looked upon more favourably

The Government, in the meanwhile, recommended to the Provisional Committee that a well-known European scientist be invited to give final shape to the project. And for this mission, the committee chose Sir William Ramsay, the British chemist who would go on to win the Nobel Prize in Chemistry in 1904.

Ramsay arrived in India in the winter of 1900 on a long trip sponsored by Tata. He studied the revised scheme carefully and also visited several cities where he met many of the stakeholders. After spending almost three months in India, he wrote his report on his way back home, eventually published as the *Report on an Institution to be named Indian Institute of Research*. Ramsay did not like the word *university* to be associated with an institution which he thought should provide scientific and technical support for the industrialisation of India. The report however sounded optimistic about the project and allayed many of the fears expressed by Curzon.
An important part of Ramsay's brief was to offer his recommendation for the location of the new Institute. And he was clearly a fan of Bangalore: the city was accessible from both Bombay and Madras, and was close to several mineral deposits like iron ore and gold. It was not far away from a promising source of electric power – Shivanasamudra Falls (Ramsay was convinced that Bangalore would be one of the largest owners of power in the world based on the Dewan's description of the planned hydro-electric project there).

An important part of Ramsay's brief was to offer his recommendation for the location of the new Institute. And he was clearly a fan of Bangalore

There were other reasons why Ramsay liked Bangalore. One, for its climate, which he believed would appeal to both Indians and Europeans alike. "The climate of Bangalore is temperate for nearly all the year; it is not too hot for Europeans, nor too cold for natives; it is within easy reach of Ootacamund [Ooty], the most bracing climate of India," he said. And two, for its lack of distractions, when compared to bigger urban centres like Bombay, Madras, and Calcutta.

"I have visited all the other proposed sites for the Institute, with the exception of Nassik [Nashik]; but no one of them appears to me to combine the advantages above alluded to," he argued.

But for Ramsay what weighed the scales decisively in favour of the city were the material promises of land and money made by the Dewan. To him the financial viability of the project was paramount.

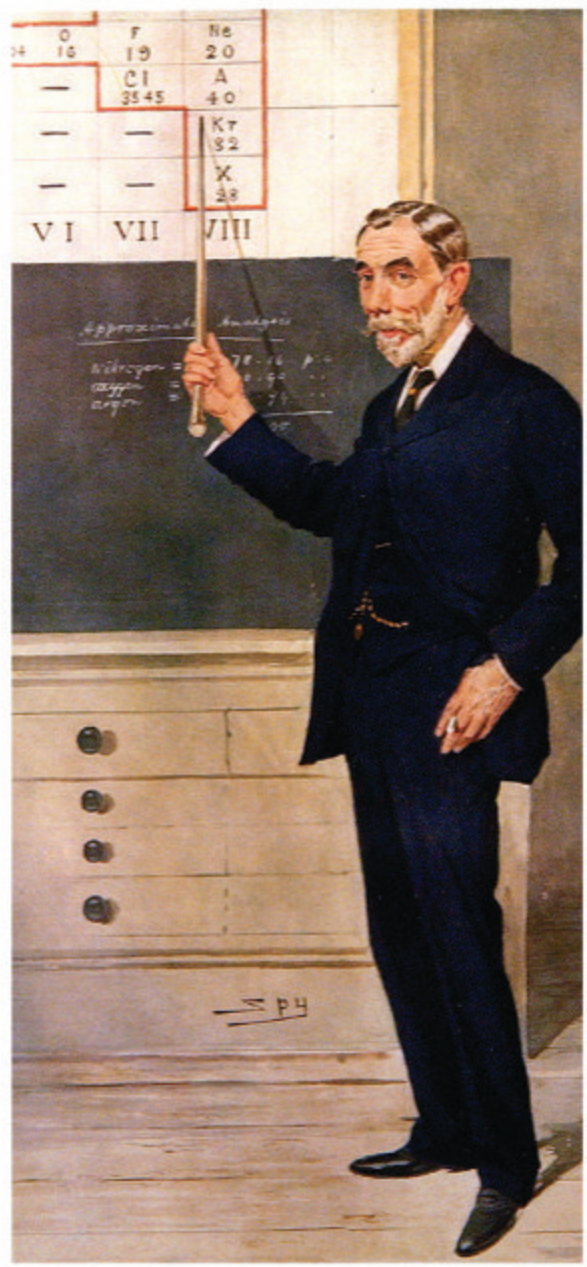


Photo credit: Leslie Ward/Creative Commons Licence/Wikimedia

A caricature of Sir William Ramsay in Vanity Fair

Once Ramsay's report was published, there were grumblings in Bengal because Ramsay had favoured a "town that was remote and devoid of intellectual society." But by now, Tata had also officially conveyed his preference for Bangalore to the Government.

At this point when it seemed like the issue of the location of the Institute was settled, there was a twist in the tale. The Government, which had concerns about some of Ramsay's suggestions, including the scale of the project, appointed another committee comprising Colonel John Clibborn, Principal of Thomason College of Civil Engineering (later renamed IIT Roorkee), and David Orme Masson, a professor from Melbourne University. After studying the scheme and Ramsay's suggestions, they submitted their own report in December 1901. Masson and Clibborn made several recommendations from what the focus of research should be to how the project could be financially downsized. They also suggested changing the name of the Institute from the *Indian Institute of Research* (which, according to them, was "pretentious") to the *Indian Institute of Science*. The report was mostly well received (an account on IISc published in *Nature* in 1924 by its first Director Morris Travers described the report as "eminently practical").

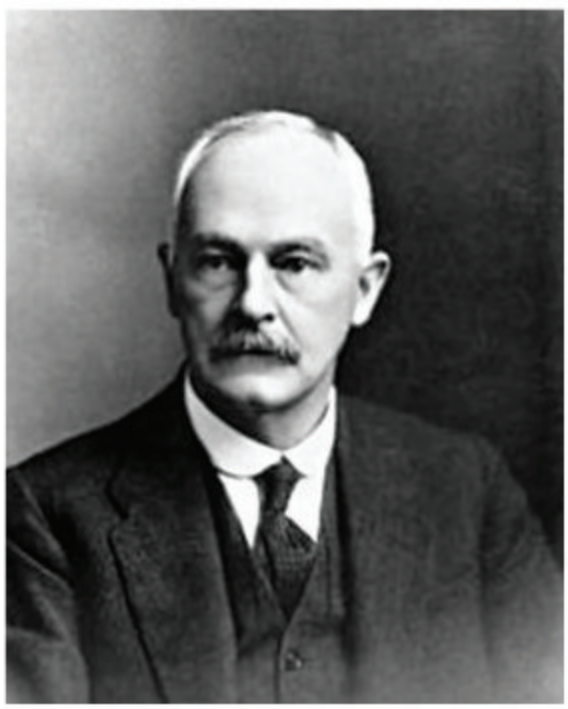


Photo credit: Creative Commons Licence/Wikimedia

David Orme Masson

What surprised many however was that the report chose to revisit the issue of the location of the Institute. The town which emerged as a dark horse late in the race was Roorkee, close to the foothills of the Himalayas, where Clibborn worked. In the report, they summarised the pros and cons of both Bangalore and Roorkee, and based on their analysis, concluded, "But, should this become possible [obtaining land and money], we are decidedly of the opinion that Roorkee is preferable to Bangalore." Roorkee also received support from the Upper India and Bengal Chambers of Commerce.

Fortunately for Bangalore, the Roorkee suggestion was stillborn because the proposed Institute did not receive the kind of patronage it required to be housed there.

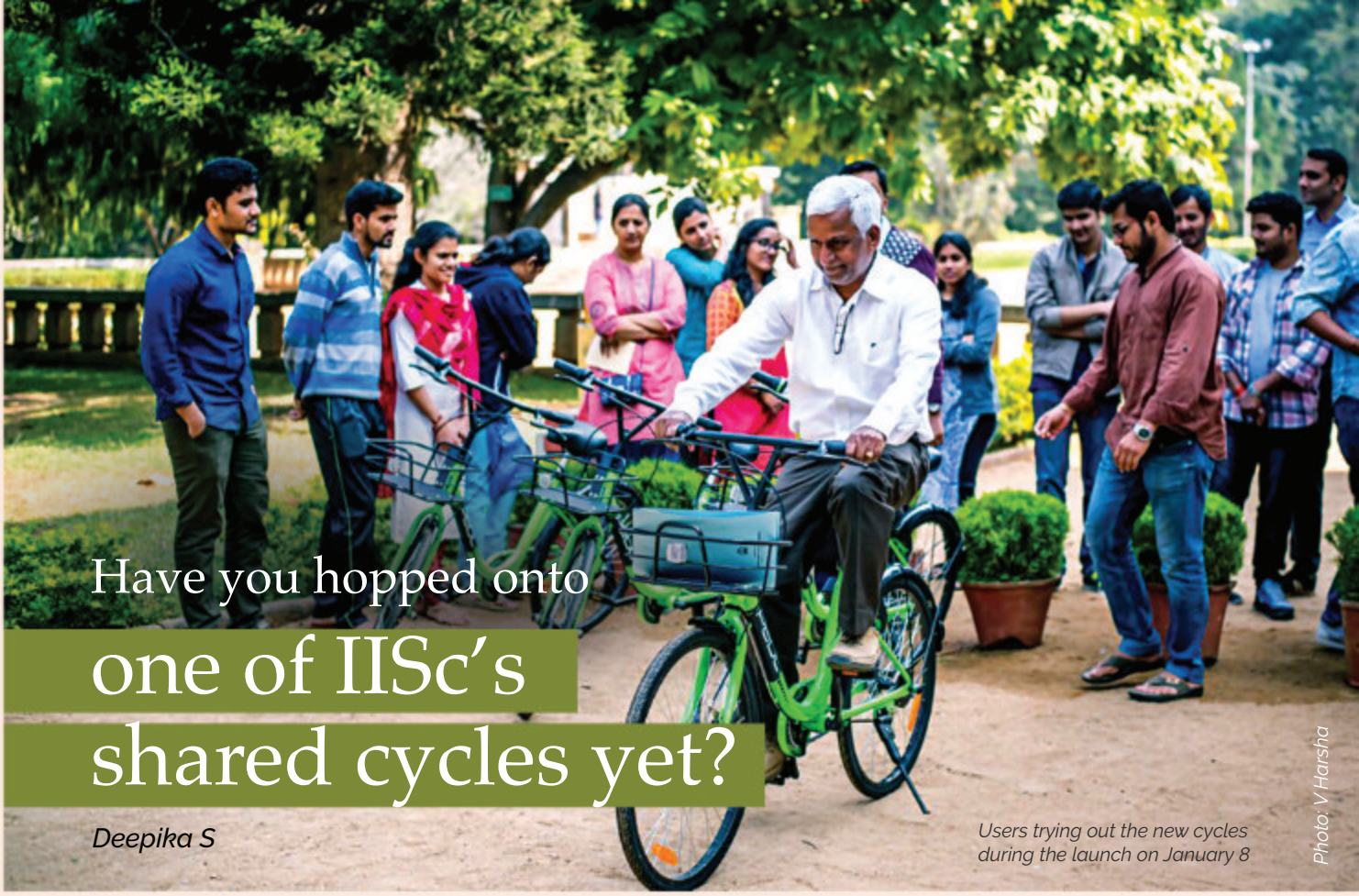
The town which emerged as a dark horse late in the race was Roorkee, close to the foothills of the Himalayas, where Clibborn worked

Even as Masson and Clibborn were writing their report, the Mysore Durbar formalised its support for the Indian Institute of Science: it promised to provide 371 acres and 11 guntas of land, Rs 5 lakhs towards capital expenditure and also an annual contribution (which was eventually Rs 50,000).

Photo: Nikhil More

Main Building of IISc in Bangalore

Not long after, Bangalore was finalised as the home of IISc. But progress on completing the formalities to set up the Institute was slow due to several bureaucratic delays as well as the sudden death of Tata in 1904. Finally, following a vesting order from the Government of India on 27 May 1909, IISc came into existence, in Bangalore, where today it occupies prime real estate in the heart of a city that has become synonymous with science and technology in India.



Have you hopped onto one of IISc's shared cycles yet?

Deepika S

Users trying out the new cycles during the launch on January 8

Photo: V Harsha

Over 100 shiny green cycles around campus are part of a smart cycle-sharing initiative called PEDL – a renewed effort to make getting around campus easy without motorised vehicles.

A collaboration between the private vehicle rental company Zoomcar and Ashish Verma's lab in the Department of Civil Engineering, the new system is meant to provide users on campus with a smooth experience and a sustainable, eco-friendly mode of transport.

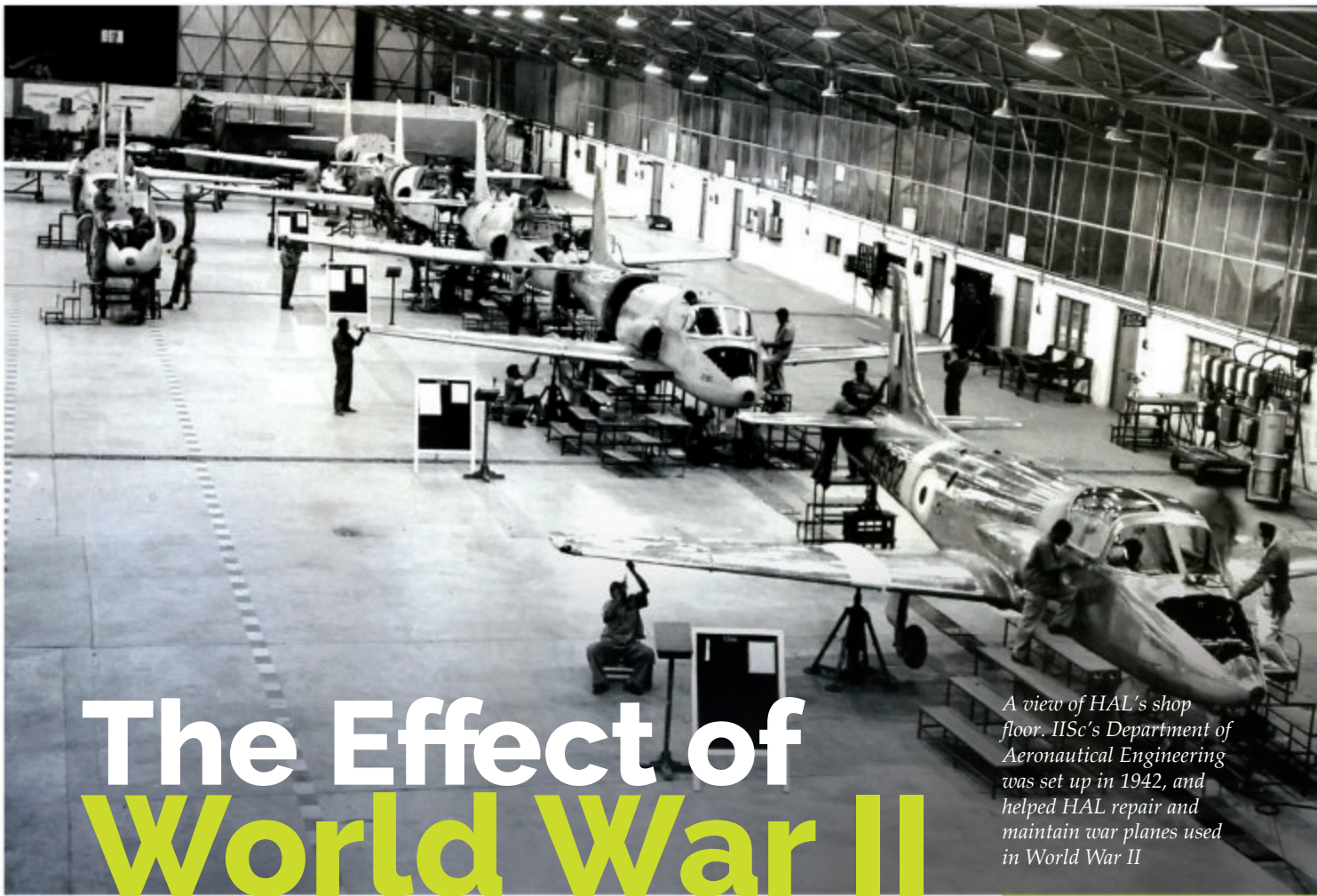
"There are 125 cycles at 27 designated locations on campus," says Verma, who is Associate Professor, Transportation Systems Engineering at the Department. "It is one step towards a long-term vision of decongesting the campus."

The cycles can be unlocked using one's smartphone, and rides cost Re 1 for every half hour of usage, which can be paid through Paytm (soon, payments by card and Unified Payments Interface – UPI – will be enabled too). More information on PEDL and how to use it can be found at www.pedl.in.

"Zoomcar shares the data with our lab, and we provide substantial input in terms of planning and analysis," says Verma. He describes PEDL – dockless, ccashless and easy to use – as the "third generation" in cycle sharing systems. Long-term denizens of IISc may remember Namma Cycle, a cycle sharing program by the Ride-a-Cycle Foundation launched on campus in 2012, which fizzled out. Verma sees it as being "first generation" – the cycles could be removed from a docking station by registering for a card and swiping them at the station. He describes the adorably named Trin Trin, a cycle-sharing system launched in Mysore that requires registration and a smartcard to use the cycles, as "second generation".

Verma sees PEDL as being particularly appealing to young users: "It's tech savvy, it's cool and trendy, and it comes with a fashion quotient." The cycles certainly have proven to be popular in their short run so far. In the first month after it launched on January 8, more than 9,500 trips had been made, with each cycle having made around three trips a day.

Sriraksha Srinivasan, a final semester MSc student at St Joseph's College, travels to IISc regularly for a project she is working on at the Solid State and Structural Chemistry Unit. She first noticed the cycles around two weeks ago, and soon became an enthusiastic user. "It's convenient because of the many locations at which they're available. It's pretty easy to figure out," she says. And they're clearly in high demand: "Earlier, you could see around five cycles at Tata Book House when you arrived," Srinivasan says. "Now, it's nearly zero."



A view of HAL's shop floor. IISc's Department of Aeronautical Engineering was set up in 1942, and helped HAL repair and maintain war planes used in World War II

The Effect of World War II on IISc

Deepika S

It took a catastrophic event like the war to reset the Institute on the course originally planned for it

"This is a time of war. The great majority of the people of this country deeply sympathise with risks and sufferings of the people of Great Britain. Many are willing and anxious to take part in the measure needed to help Britain and humanity in this emergency," said engineer and statesman Sir M Visvesvaraya in his 1941 address to members of IISc's Court.

It may be hard to gauge whether Visvesvaraya's statement truly reflected the sentiments of the most Indians, but World War II, which broke out on 1 September 1939, had a considerable impact on India. Being a British colony, India was drawn into the war (which would come to Indian shores with the bombing of the southern coast in 1943 and the attempted invasions of Kohima and Imphal by Japan the following year), and provided resources and manpower – by August 1945, over 2.5 million Indian men had fought for the Allies. With a war spanning six years (ending in September 1945) and independence on the horizon, the British-ruled country was faced with new challenges, including a need to rapidly develop local industry and scientific research. These challenges would pull IISc in a significant new direction.

In 1938, Visvesvaraya was unanimously elected President of IISc's Court – which takes decisions on important matters such as the setting up of new

Photo: APC, IISc

departments and the Institute's direction – and remained President until 1947. The minutes of the Court proceedings from those years include his annual opening address to the members of the Court, and reveal a rather dogged focus on ensuring that IISc's research activities expanded to include applied research.

By the time war broke out, three committees had reviewed the work done by the Institute – the Pope Committee appointed in 1921, and the two "Quinquennial Reviewing Committees" in 1931 and 1936, known as the Sewell and Irvine committees, respectively. All three recommended that the Institute focus on industrial research. But a lack of funds, and the personal inclinations of IISc's directors (who had included scientists focused on pure research like Morris Travers and CV Raman) until then, had meant that the founder JN Tata's vision of building an institute that would support industry was yet to be realised.

To Visvesvaraya (who is supposed to have said "Industrialise or perish"), World War II seemed to provide the perfect impetus. "Industries of a country in war time stimulate self-help and have a bracing effect on the mentality and aspirations of the people," he said in 1941, quoting a member of the Central Legislative Assembly who had been impatient about Indians being called upon to subscribe to war loans and give to war funds and "knit stockings, but nothing more". "Our failure to take advantage of the present opportunity to give a fillip to industries," Visvesvaraya told the Court, "will mean a tragic waste of a chance which occurs only once in several generations."

The first major decision towards this end was the passing of a resolution in 1941 to provide training in aeronautical and automobile engineering. In 1942, this was extended to mechanical engineering ("The War that is going on," Visvesvaraya believed, "is a mechanical engineer's war.") In 1944, a Joint Committee of IISc's Court and Council to drive applied research put forth nine proposals, including the setting up of new departments in Applied Mechanics and Metallurgy, the splitting of the Department of Electrical Technology into the departments of Electrical Engineering (with a focus purely on research) and Communication Engineering, the expanding of the course in chemical engineering, and the setting up of a first class Research Workshop under the proposed Department of Mechanical Engineering.

Photo courtesy: APC, IISc

A 1943 photograph of students of the Department of Electrical Technology standing before a 300 Watt transmitter they designed and fabricated for the Royal Air Force, for communication with London during World War II

When war broke in 1939, only four departments were in operation: Physics, General and Organic Chemistry, Biochemistry and Electrical Technology. By the end of the war, Aeronautical Engineering had been added, along with a course in Internal Combustion Engineering. A course in Metallurgy would follow soon after.

IISc's war activities

Apart from having a long-term influence on the direction of research at IISc, the war had a significant immediate impact on the daily activities in the departments and on campus.

The minutes of the Court proceedings of 1941 and 1942 show that work carried out for the war included the manufacture of activated carbon for gas masks, radio equipment, urea and formaldehyde required to make synthetic plastic materials, drugs and allied substances for the Army, among other things. Staff from the Institute helped set up factories to produce bichromate, and chlorates of barium and potassium. The Institute's Central Workshop had been stocked by the Government of India with a large number of lathes, and machines for purposes such as drilling, shaping, grinding and milling.

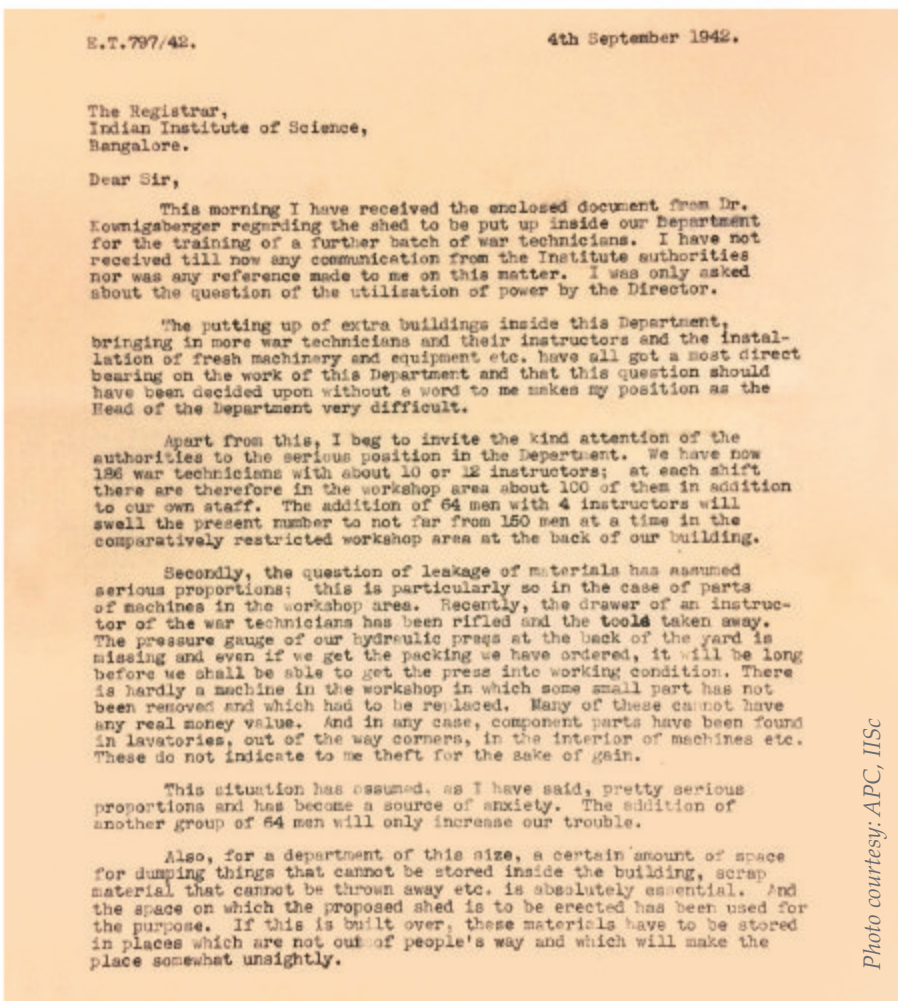
IISc's Annual Reports from the war years show that the Institute provided facilities to train "skilled artisans" such as electricians, machinists, carpenters, tin and copper smiths, among others. On the request of the Air Headquarters of the Military, a plant was constructed on campus for the large-scale production of hydrogen gas, and the Institute temporarily leased 108 acres of land to the military authorities as a camp site, 30 acres for the setting up of a military radio service, and other locations on campus for the construction of workshops. Clerks were even trained in type-writing and English composition.

Of course, the transition into war mode wasn't always smooth. Letters between architect Otto Koenigsberger, IISc's administration, and the head of the Department of Electrical Technology, K Srinivasan, show that the new arrangements could sometimes be a source of friction.

Looking beyond the war

The war, coming as it did right before Indian independence, led to changes at the Institute that also reflected a change in attitude. The Quinquennial Review Committee was not appointed in 1941, when it was due, on account of the war. "That Committee has the great disadvantage," Visvesvaraya said in his Court address the following year, "of not always understanding local conditions and local wants." He went on to propose that rather than have foreign scientists arrive to assess the Institute after the close of the war, the Institute should send members to centres of scientific and educational activities in foreign countries to gather ideas. By 1944, steps were being made by the Institute to move beyond the war and begin the process of nation-building – something Visvesvaraya was keen to drive.

"Happily the war has ended," Visvesvaraya told the Court in 1946, "and the post-war peace time activities are engaging the attention of every free country. The great changes that have taken place as a result of the two World Wars and the progress and discoveries in science, which are also partly the result of the wars, have altered living conditions in many parts of the world." Ironically, it took a development as catastrophic as a World War for IISc to reset its course towards the path originally intended for it. The Institute's new direction from the war led to several fruitful collaborations, chief of which is the growth of India's aerospace industry, where the Institute still plays a significant role.



E.T.797/42. 4th September 1942.

The Registrar,
Indian Institute of Science,
Bangalore.

Dear Sir,

This morning I have received the enclosed document from Dr. Koenigsberger regarding the shed to be put up inside our Department for the training of a further batch of war technicians. I have not received till now any communication from the Institute authorities nor was any reference made to me on this matter. I was only asked about the question of the utilisation of power by the Director.

The putting up of extra buildings inside this Department, bringing in more war technicians and their instructors and the installation of fresh machinery and equipment etc. have all got a most direct bearing on the work of this Department and that this question should have been decided upon without a word to me makes my position as the Head of the Department very difficult.

Apart from this, I beg to invite the kind attention of the authorities to the serious position in the Department. We have now 186 war technicians with about 10 or 12 instructors; at each shift there are therefore in the workshop area about 100 of them in addition to our own staff. The addition of 64 men with 4 instructors will swell the present number to not far from 150 men at a time in the comparatively restricted workshop area at the back of our building.

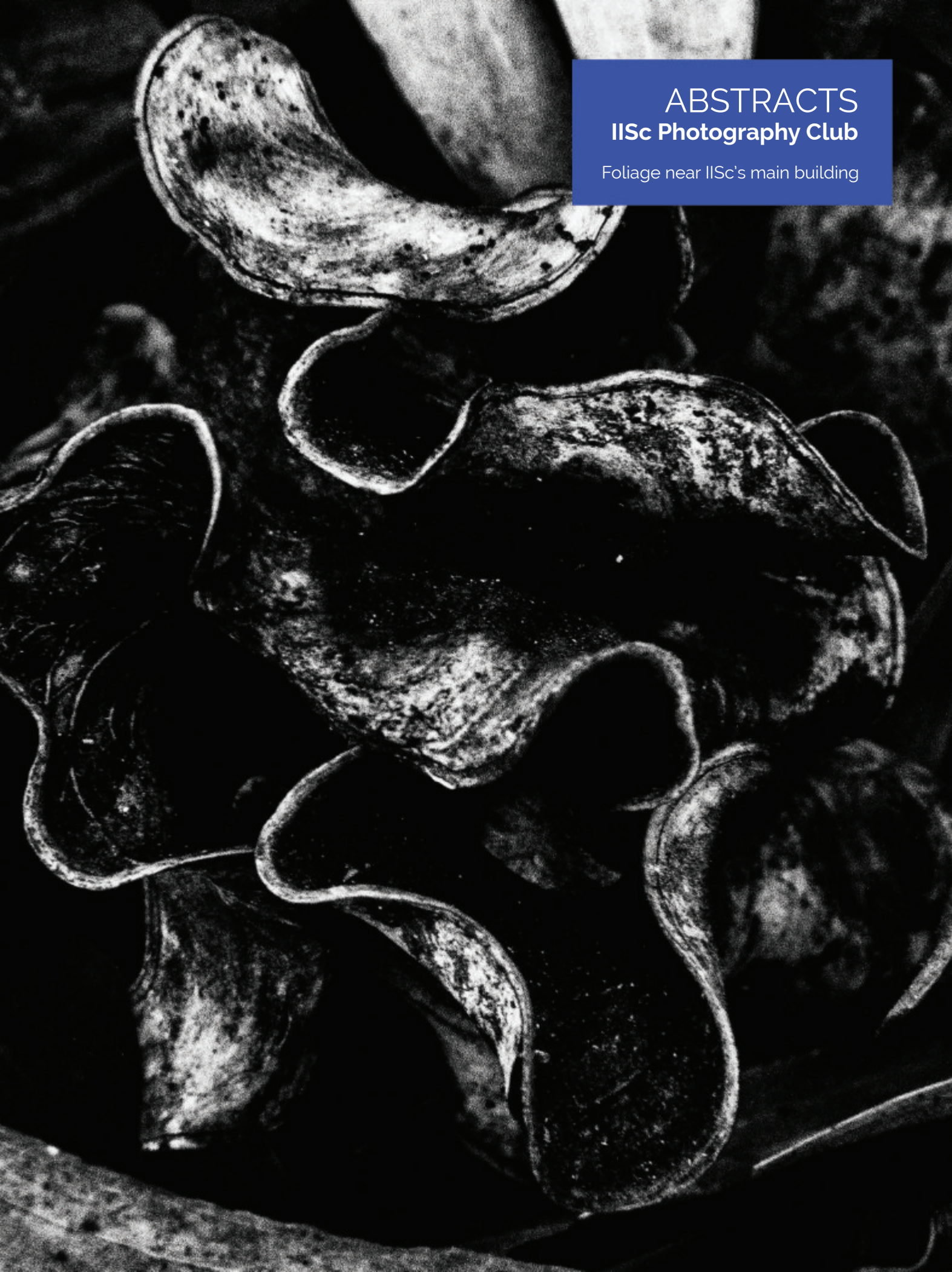
Secondly, the question of leakage of materials has assumed serious proportions; this is particularly so in the case of parts of machines in the workshop area. Recently, the drawer of an instructor of the war technicians has been rifled and the tools taken away. The pressure gauge of our hydraulic pregs at the back of the yard is missing and even if we get the packing we have ordered, it will be long before we shall be able to get the press into working condition. There is hardly a machine in the workshop in which some small part has not been removed and which had to be replaced. Many of these cannot have any real money value. And in any case, component parts have been found in lavatories, out of the way corners, in the interior of machines etc. These do not indicate to me theft for the sake of gain.

This situation has assumed, as I have said, pretty serious proportions and has become a source of anxiety. The addition of another group of 64 men will only increase our trouble.

Also, for a department of this size, a certain amount of space for dumping things that cannot be stored inside the building, scrap material that cannot be thrown away etc. is absolutely essential. And the space on which the proposed shed is to be erected has been used for the purpose. If this is built over, these materials have to be stored in places which are not out of people's way and which will make the place somewhat unsightly.

Photo courtesy: APC, IISc

Portion of a letter from K Srinivasan, head of the Department of Electrical Technology, to IISc's Registrar raising concerns about the war arrangements



ABSTRACTS

IISc Photography Club

Foliage near IISc's main building