Research Methodology, Ethics & Communication
An ICTS Core course

Instructor : R. Loganayagam.

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1 Basic Info :

- **Instructor name :** R.Loganayagam,
- **Venue :** Zoom.
- **Timings :** Monday 17:00 - 18:30 Hrs, Thursday 16:00 - 17:30 Hrs
- **First Class (Introduction) :** Thursday 16:00 - 17:30 Hrs, 11th Feb, 2021
- There will be no drop test for this course.
- **The grading policy** will be based on the following weightage :
  - Class participation/presentations : 50%
  - Written Assignments : 50%

2 Prerequisites:

You will be doing a lot of writing in this course. The writings have to be submitted in LaTeX format. I will assume that all of you are familar with basic high school level English grammar and composition at the level of the textbook by Wren and Martin. For LaTeX, searching online as you write is the quickest way. Here are some resources I have found useful :

- LaTeX in 24 Hours : A Practical Guide for Scientific Writing by Dilip Datta
  `https://link.springer.com/book/10.1007%2F978-3-319-47831-9`
- More Math Into LaTeX by George Grätzer
  `https://www.springer.com/gp/book/9783319237954`
- LaTeX and Friends by Marc van Dongen
  `https://www.springer.com/gp/book/9783642238154`
- LaTeX templates : `https://www.latextemplates.com/`
- LaTeX resources by Ryan Higginbottom
  `http://www2.washjeff.edu/users/rhigginbottom/latex/resources.html`

Many of the core topics of this course have an overlap with philosophy. The relevant fields here are Epistemology (dealing with knowledge), Ethics (dealing with morality), Logic and Rhetoric (dealing with debate, argument and persuasion). We will also be interested in history and sociology of science which contain many valuable insights on how research has been done in the past. Our attitude towards all these subjects in this course would be similar to how say mathematics is treated within the physics core courses: we will acknowledge it as essential and try our best not to oversimplify the perspectives provided by these fields. At the same time, we will also take a pragmatic approach that steers clear of deep waters. Some good references on philosophy of science are

- Philosophy of Science for Scientists by Lars-Göran Johansson
- Worldviews: An Introduction to the History and Philosophy of Science
  by Richard DeWitt
- An Introduction to the Philosophy of Science by Kent W. Staley
- Theory and Reality – An Introduction to the Philosophy of Science by Peter Godfrey–smith
- Stanford Encyclopedia of Philosophy
  `https://plato.stanford.edu/contents.html`

The Stanford Encyclopedia is often a useful resource with accessible summaries of relevant issues. While I do not expect students to have a familiarity with the topics discussed in above references, an openness to consider them as they go along is a pre-requisite.

An elementary discussion of probability and statistics (including error analysis) can be found in the following undergraduate texts :

- Introduction to Probability And Statistics for Engineers and Scientists
  by Sheldon M.Ross

- Probability and Statistics for Engineers and Scientists
  by Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers, Keying E. Ye .
- Measurements and their Uncertainties: A practical guide to modern error analysis
  by Ifan Hughes, Thomas Hase
- Introduction To Error Analysis: The Study of Uncertainties in Physical Measurements
  by John R. Taylor
- Research Methods For Science by Michael P. Marder

Policy on online classes/privacy :

The online nature of the course that has been forced on us by these pandemic times. While it has opened up new opportunities, its predominant effect has been a negative effect on the student interactions/feedback and assessment of student progress. A recognition of these limitations and a commitment to overcome them (both on the side of students as well as the instructor/tutors) is necessary for a course like this to succeed. I hope the students take a pro-active role.

In order to encourage frank assessments and discussions, this course will be restricted to present ICTS graduate students. Especially, it is expected that the Zoom links and video recordings of classes would be access-restricted and I expect the students to respect the online privacy of their peers in keeping it so.

3 Plan for the course

My plan for this course is to have roughly four modules, each covering a month in the semester. I would characterise these modules roughly as follows:

1. The Craft of Research (Research Methodology) and Critical Thinking
2. Research ethics, Issues and Debates within Indian Science
3. Scientific writing
4. Scientific Talk and Presentation, Public Speaking and Outreach

In this section I will elaborate more on what comes under these topics. The next section has a list of suggested references for this course. We then end this note with three brief essays on the broader philosophy of the course.

We will begin the first module with the discussion of what constitutes science, the idea of so called scientific method and the limitations of thinking about science that way. This will involve looking at some well-known models proposed by historians, philosophers and sociologists of science on how scientific research is done along with a discussion of the limitations of such models. After this brief introduction, we will move on to a discussion of what constitutes a good research problem and the art of identifying one. The third part of this module would be about critical thinking and critical reading of scientific literature. We will end the module with a fourth part on use and abuse of statistics within scientific literature. This module is designed to have a series of reading/writing assignments.

The second module will be on research ethics. We will begin this module with a broader discussion of the ethical frameworks useful in analysis of ethical problems. We will then move on to discussing ethical misconduct involving fabrication, falsification of data as well as writing useless papers. The third part of this module would be about our ethical commitments to rest of scientific community. This involves an array of topics including authorship, citation, plagiarism, mentorship, conflicts of interest, confidentiality in peer review and so on. We will end this module with a discussion of scientists role in a society with some special attention to the Indian context. There is again a long list of ideas which come under this broad topic including diversity issues within scientific community, interactions with society, approach towards superstition and pseudo-science and the impact of political, religious and socio-economic ideologies on scientific research. This module will also have a series of case studies drawn from the suggested texts as well as elsewhere.

The third module will be on scientific writing. We will start by discussing general attitudes to writing including how to deal with the so called writers' block. We will then move on to a detailed discussion of the content and structure of scientific documents of various kinds (proposals, reports, papers, reviews etc.). We will discuss the nature of abstracts, the canonical IMRaD structure and perfectly sensible deviations from it. The third module will be about style in scientific writing. We will end with a discussion of other forms of writing including research summaries, reply to referees etc. This plan broadly follows the nice textbook by Stephen Heard suggested in the references. This module will (obviously!) involve a lot of writing.

The fourth module will be on scientific presentations and public speaking. We will start with an introduction to rhetoric or the art of persuasive argumentation. We will then begin by discussing what a scientific talk should include given a specific audience and more importantly what it should *not* include. This discussion on contents will be followed by a discussion the structure : both conceptual as well as how visual aids like slides should be structured.We will end with a discussion about delivery of talks and presentations. I will require students to give many presentations as well as analyse talks in this module.

The reader would recognise that this is an ambitious plan ! Each of this modules could very well be extended to an entire semester themselves. Given that this is the first time this course is being offered, I expect that we will have to cut corners to make it into a managable course. As in other core courses, the aim here is to basically familiarise students with the ideas involved and insist on basic competence. It is assumed that the students will improve upon this over their PhD years as well as afterwards. Given the nature of this course, I will insist on high level of student participation- much higher than what is expected in other courses.

4 Suggested references

Given the contents described before as well as the inherent nature of this course, no single textbook could cover the entirety. With this caveat I give below a set of texts which have appealed to me at various levels. Please contact me in person if you wanted to know about my individual opinion on these texts including their strengths and weaknesses.

Unfortunately there seem to be many not very good books on these issues and I have read and rejected many of this sort. Originally this list was supposed to include an array of books on history/sociology of science but I could not come up with a balanced list in time. Another shortcoming of this list is the absence of online resources- video lectures, podcasts, essays etc. I plan to rectify these in due course.

On Research :

- The Craft of Research by Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams, Joseph Bizup, and William T. Fitzgerald.
- The Art of Being a Scientist by Roel Snieder and Ken Larner
- The Unwritten Rules of PhD Research by Marian Petre and Gordon Rugg
- Advice to a Young Scientist by Peter Medawar
- The art of scientific investigation by William Ian Beardmore Beveridge
- Ignorance: How It Drives Science by Stuart Firestein
- Failure: Why Science Is So Successful by Stuart Firestein
- What Science Is and How It Really Works by James C. Zimring

On Critical thinking :

- Critical Thinking Skills by Stella Cottrell
- A Workbook for Arguments: A Complete Course in Critical Thinking by Anthony Weston and David R. Morrow
- Critical Reading and Writing for Postgraduates by Alison Wray and Mike Wallace
- Critical Thinking Skills For Dummies by Martin Cohen
- The Critical Thinking Toolkit by Galen A. Foresman, Jamie Carlin Watson, and Peter S. Fosl
- Pseudoscience and Extraordinary Claims of the Paranormal : A Critical Thinker's Toolkit by Jonathan C. Smith

On Research Ethics :

- Elements of Ethics for Physical Scientists by Sandra C. Greer
- Research Ethics for Scientists: A Companion for Students by C. Neal Stewart Jr.
- Ethics in Science: Ethical Misconduct in Scientific Research by John D'Angelo
- Scientific Misconduct Training Workbook by John D'Angelo
- The Ethical Chemist by Jeffrey Kovac
- Betrayers of the Truth: Fraud and Deceit in the Halls of Science
  by William Broad and Nicholas Wade
- Research Ethics: A Philosophical Guide to the Responsible Conduct of Research
  by Gary Comstock

Scientific Writing :

- The Scientist's Guide to Writing by Stephen B. Heard
- How to Write and Publish a Scientific Paper by Barbara Gastel, Robert A. Day
- Writing Science by Joshua Schimel
- The Craft of Scientific Writing by Michael Alley
  `https://link.springer.com/book/10.1007%2F978-1-4419-8288-9`
  `https://www.craftofscientificwriting.com/lessons.html`
- A Field Guide for Science Writers
  edited by Deborah Blum, Mary Knudson, and Robin Marantz Henig
- They Say / I Say: The Moves That Matter in Academic Writing
  by Cathy Birkenstein and Gerald Graff
- Mastering Academic Writing in the Sciences: A Step-by-Step Guide
  by Marialuisa Aliotta
- Academic Writing for Graduate Students by Christine B. Feak and John Swales
- Becoming an Academic Writer by Patricia Goodson
- Writing for Science Students by Jennifer Boyle and Scott Ramsay
- The Chicago Guide to Communicating Science by Scott L. Montgomery

Style Guides :

- The Elements of Style by Strunk and White
- Style: Lessons in Clarity and Grace by Williams and Bizup
- The Sense of Style by Steven Pinker
- On Writing Well by William Zinsser

Speaking :

- A Handbook of Public Speaking for Scientists and Engineers by Peter Kenny
- The Craft of Scientific Presentations by Michael Alley
  `https://link.springer.com/book/10.1007/978-1-4419-8279-7`
- When the Scientist Presents by Jean-Luc Lebrun

5 Course Philosophy

tāh sarvāh samavekṣyāvekṣya sarvaṃ vākyam brūyāt,
nāprakṛtakam aśāstram aparīkṣitam asādhakam ākulam avyāpakam vā.
sarvaṃ ca hetumad brūyāt. hetumanto hy akaluṣāh eva vādavigrahāś cikitse kāraṇabhūtāh,
praśastabuddhihvardhakatvāt; sarvārambhasiddhiṃ hy āvahaty anupahatā buddhiḥ.

–Caraka-saṃhitā Vimānasthāna (8.67)

One should make every argument after having thoroughly considered all these, not [saying] what is irrelevant or not part of the discipline, what is unproved, inconclusive, disordered, or incomprehensible. And everything one says should be well-founded. For all discussions and disputes that are well-founded and clear become a means of healing because they increase the praiseworthy intellect, and an unimpaired intellect leads to the accomplishment of all undertakings.

–Translation by Dagmar Wujastyk
from *Well-Mannered Medicine, Medical Ethics and Etiquette in Classical Ayurveda*

Don't degrade me into the position of giving you useful information.
Education is an admirable thing,
but it is well to remember from time to time
that nothing that is worth knowing can be taught...
Thought is wonderful, but adventure is more wonderful still.
–Oscar Wilde (The Critic As Artist)

The rationale for this course comes from the belief that there is a certain value in having our graduate students think about research, about ethics, about writing, about talks etc., seriously right from their first year. There are two aspects to this statement : first of all that these topics belong together and should be learnt/taught together. Second that these ideas can indeed be taught in a classroom setting. Neither of these ideas are self-evident and so a justification is in order.

Scientific community

What does communication(writing/talks etc.) have to do with 'scientific method' ? In turn, why should these two be linked with issues on research ethics ? The crucial links between these ideas not at all obvious to a beginning graduate student and even seasoned researchers often only understand these relationships at a very vague intuitive level.

To clarify the link let me begin by justifying the following assertion : Scientific communication is the foundation of science. Why ?

As scientists, we assume by default that individual human beings are prone to mistakes. They are biased by their prejudices and overlook crucial facts that contradict their hypothesis. Having accepted this fact, how do we do science at all ? How do we ever hope to find scientific truths about nature ?

In my opinion, the crucial answer that the so called scientific method provides to this dilemma is this : while individuals are fallible, a *scientific community* can be used to make progress. The concept can be roughly described as follows : an individual with an idea or an observation communicates it *clearly and honestly* to a scientific community. This is done by speaking and writing about the idea, providing proper context, details and caveats with due honesty. Other individuals in the scientific community listen to, question, test, debate and critique the idea or the observation in good faith. This critical assessment is then communicated back clearly and honestly to the original person. The hope then is that this cycle of careful tests and observations, clear speaking and writing, critical reading and listening within an intellectually diverse, an ethically committed and socially connected community help us overcome our individual shortcomings. That this can be done is not self-evident but this remarkable idea has broadly withstood the tests of history.

We do science by creating a scientific community and by building institutions which support such a community. We foster communication by means of our talks, lectures, colloquia, workshops, conferences, papers, reports and journals. We encourage a culture of careful thinking, scepticism, honesty, hard work, ethical conduct and congeniality by fostering good practices within these institutions. We inspire each other by our questions, by our curiosity, by our courage, by our hard work, by our excellence, by our ethical standards, by our ambition, by our friendships, by our collaborations and by our rivalry. This description should make it clear that ethics and communication are not an afterthought in science, but rather the very bedrock on which science is built.

This is why birth of modern science in history is marked by spreading of the printing press, an increase in literacy, the development of papers and journals, the formation of universities and scientific societies which encouraged 'gentlemanly' conduct, scepticism and honesty. This is why the history of physics, of Science, of Europe and the world at large were substantially transformed with the creation of say the Royal Society and the emergence of the Republic of Letters. This explains why the world wide web was invented by scientists to talk to other scientists. This is the major reason why an individual is often more productive, when he/she is a part of a larger well-connected scientific community which values hard work, creativity, competition, critical thinking, ethical conduct and clear communication. This is also why, here in ICTS, we strive to encourage seminars, workshops, conferences and outreach.

A little thought should convince the reader that, without scientific communication, without critical evaluation and without a minimum ethical commitment, the scientific method cannot operate on an idea or an observation. It follows that *an idea or an observation becomes science only when it is communicated clearly, received critically and is deemed trustworthy. An idea can claim to be a part of scientific endeavour only when the relation between it and the other ideas have been checked and clarified in a variety of different settings.*

As scientists, we try to be precise and logical in our thinking, writing and speaking as well as in our reading and listening. We act in good faith: we strive to trust and be trusted, strive to understand and to be understood, strive to question and be questioned. To be a good scientist is to be a good thinker, a good listener, a good writer, a good speaker and a good communicator. We spend a lot of time anticipating the questions that our potential audience would ask, and how those queries can be addressed appropriately. We also try, despite our deeply held prejudices, to be best possible critics of what other scientists have to offer.

It is against this idealised (some might say over-romanticised) picture of the scientific community that we can judge our failures. While last few centuries have seen great progress driven by sciences, the history of science is also filled with missteps and mishaps (also many outright frauds and cases of blatant prejudices). There is much that is fallible in human nature and many such flaws hitch-hike onto the scientific process. It is thus essential that practising scientists learn to diagnose and deal with such failures.

A more cynical line of argument for the same conclusion is as follows : the scientific community (like other communities built on social, political, economic or religious similarities) have certain aims and aspirations. Like any other human community, these aspirations are achieved by procuring access to money, talent, social recognition, state power etc. This is, in turn, achieved by co-opting and contesting existing human institutions to achieve certain ends. Phrased this way, we are inevitably led to ask: which kind of aspirations are legitimate? what kind of scientific agendas and access to power are morally defensible ? Such questions almost never have simple answers. But to sweep these questions under the carpet, to ignore them, eventually imperils the entire scientific community. Scientists cannot play naive when so many social, political, economic/religious agendas seek to co-opt scientific research and hard-earned scientific prestige for their own ends.

The above description shows how the various ideas in this course are intimately linked. To summarise, scientific method is about scientific community and the scientific community is built on certain foundational commitments : commitments of creativity and hard work, of critical thinking and constructive scepticism, of honesty and ethical conduct, of clear communication of what one thinks and knows. Once these facts are recognised, it becomes clear why a graduate student should be trained in all these skills in order to do research.

Why a course ?

Say we accept the argument sketched above. Does it follow that the right way to do it is through a course ? Whenever I mention my intention to teach a course on research methodology, ethics and communication, the first reaction of many of my colleagues (faculty, postdocs, students)is scepticism. Is there a fixed methodology to do research ? Are there a set of simple rules which resolve complex ethical problems that researchers encounter ? Is there a specific way all scientists *have* to communicate ? Even if we assume these exist, can it really be taught ? Even if it can be taught, is it possible to teach it in a course rather than via actual practice of research (say in research projects) and via one on one interactions ? Many believe that the answers to all these questions is a big no ! Hence the scepticism.

Let me say right away that I think I understand and agree with this opinion to some extent. However I disagree with the core of this argument. A similar pessimism can be extended to all of education including the core physics courses taught to our graduate students. Can one really understand a subject like statistical mechanics from lectures alone ? This pessimism however has not stopped us from writing textbooks and giving lecture courses on such subjects. One of the most famous lectures in our subject given by Feynman contains a preface where Feynman expresses his scepticism for lecture courses !

I think however most of us will admit that, despite all the inefficiencies, it is better to have our students attend such courses than not having those lectures at all. While no amount of lecturing can substitute for actual practice, lecture courses still valuable so far as they inspire people to go out, think and practice in new ways.

I think a similar argument justifies this course. There is indeed a sense in which teaching 'research methodology' to beginning graduate students is like teaching the theory of cookery to those who cannot even boil water without setting the house on fire. Even so, I will argue perhaps the combination of practical assignments and research projects etc., would take care of the not-setting-the-house-on-fire part of their training.

At a personal level, the motivation to teach such a course stems from the following fact : over the past few years, I find myself repeating various basic truisms about research, ethics and writing while mentoring graduate students. I also believe that the traditional model where we expect these to be known already or learnt by osmosis is failing as education is extended beyond the elites for the first time in our national history. There is a clear need to consciously train our students, to tell them what is expected of them and what they can in turn expect as they embark into research.

I also think some of the above mentioned scepticism is born out of elite privilege. Those of us who have well-read urban parents, scholars in our extended family and book collections that go back many generations digested during high school holidays, are no strangers to good writing. Those of us who have debated their way through high schools do not need some book or a lecture to tell us how to present an argument. When it comes to graduate school, such people might stumble here and there on the peculiarities of scientific communication but the general principles are familiar from before. For them, what is needed can be picked up along the way and the idea of such a course sounds quaint to their ears. The reality however is that many of our students do not come from such backgrounds.

I will conclude this argument by mentioning that, in the context of ethics, the scepticism of whether it can be taught at all indeed has a long philosophical pedigree, e.g., note the Socratic dialogues with Meno (as described by Plato). The argument for the efficacy of say ethical instruction also has a long philosophical pedigree. After all, such a system of instruction was the bedrock of the society as imagined by Kongzi(Confucius), Menzi and Xunzi. It is these debates which over centuries led eventually to the system of public examinations and the assessment of merit via tests. This is not a place to review these arguments except to say that the long Chinese history bears testimony to the grand successes and deep limitations of this mode of moral cultivation.

5.1 On writing

Of all forms of scientific communication, writing is the most elaborate and the most durable. As a part of your graduate study, you will be required to write a lot : in term papers, thesis proposal, research papers, referee reports, reply to referee reports, assessments, talk abstracts, posters and finally the PhD synopsis and thesis. If you choose to pursue a scientific career further, more writing will be called for over and above these forms : in recommendation letters, review articles, lecture notes, assignments, grant proposals, conference proposals, textbooks, news articles, press releases and progress reports. It is truly mind-boggling to contemplate how much writing dominates the academic life. To a first approximation, scientists are one of the prolific writers. Not just that, most of them are also exceptional how much their writing is multi-authored. Given these facts, the earlier you learn to write well, the better it is.

The first rule of writing is that good writing takes time and effort. As in all creative endeavours, good writing is often a lifelong pursuit. The good news is that writing can be learnt by practice, feedback and self evaluation.

Often beginning graduate students have a mistaken impression about research writing. Many have the following flawed idea of how a paper is written : In the first step, one learns lots and lots of *stuff.* Next, by some mysterious means, a problem is formulated. One then begins computations and in due time finishes them. Then, the researcher sits down on a day to pour everything out of his/her brain into a document. This cartoon picture of research and research writing is quite far from reality.

The flaws in thinking of research this way are too many to enumerate. A main flaw is to think that writing happens at the end and solely for the sake of communication. It completely misses the crucial fact that **writing is a central tool for research and critical thinking. It is not merely a mode of communication !** The reality is that you need to start writing from the very beginning. Every step mentioned above requires writing : you learn new things by writing about them. You stumble on problems and figure out what needs to be done by writing. You keep track of computations by writing. You find flaws in your logic by writing. In short, research is done by writing at every step.

Why do you need to start writing right from the start ? Here are some reasons :

- Many a times, only after you start writing, do you realise that an apparently brilliant line of argument is actually full of logical holes. Writing with repeated revision is a powerful tool for analysis of ideas. For one, a written note helps us develop a critical stance towards our own ideas and arguments.

- Often at the end of a project, you might be bored and exhausted and perhaps a deadline is hanging above your head. Perhaps you have moved on to new computations. If you have not written anything till then, it is probable that you cannot write anything, let alone write well or give the scientific idea the time and effort it deserves.

  Further, one of the worst nightmares for an active physicist is to be 'scooped', i.e., somebody else may publish an idea/result that you have been working on for months/years. Sometimes, you need to then respond by publishing immediately and you will need a well-written document to pull that off.

- The power of ideas expressed in a written text should not be underestimated. It sparks new ideas and allows us to see connections between ideas. It allows us to recursively build arguments over other arguments and clarifies their structure. It stands the test of time even after all of us are dead and decomposed. It is for this reason written texts are used with great effect by literature, law, science and religion.

- If you are collaborating with others in your research, a written note helps others understand what you have done. Writing is a powerful form of communication and an essential tool in collaboration.

- I think every scientist has their own scientific voice, i.e., the way one phrases the ideas and draws connections. Every single person has their own scientific style and scientific accent. In my opinion, an important goal of PhD is to find one's own scientific voice. Thus, it is especially important for a beginning scientist to learn to write, for writing is the best way to discover one's own scientific voice.

One can go on in a similar vein, but hopefully these reasons are sufficient to convince you why it is important to start writing from the very beginning.