SCIENTIFIC RESEARCH METHODOLOGIES AND TECHNIQUES

Unit 1: INTRODUCTION

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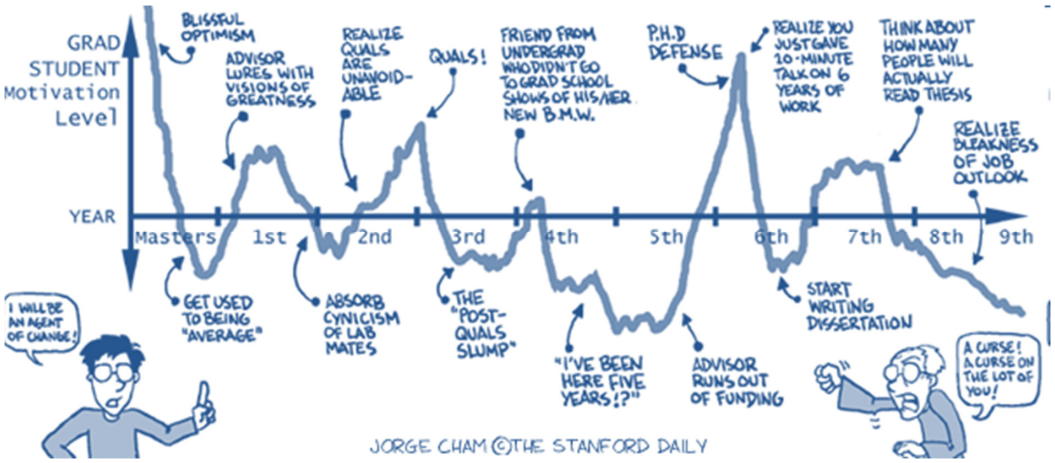
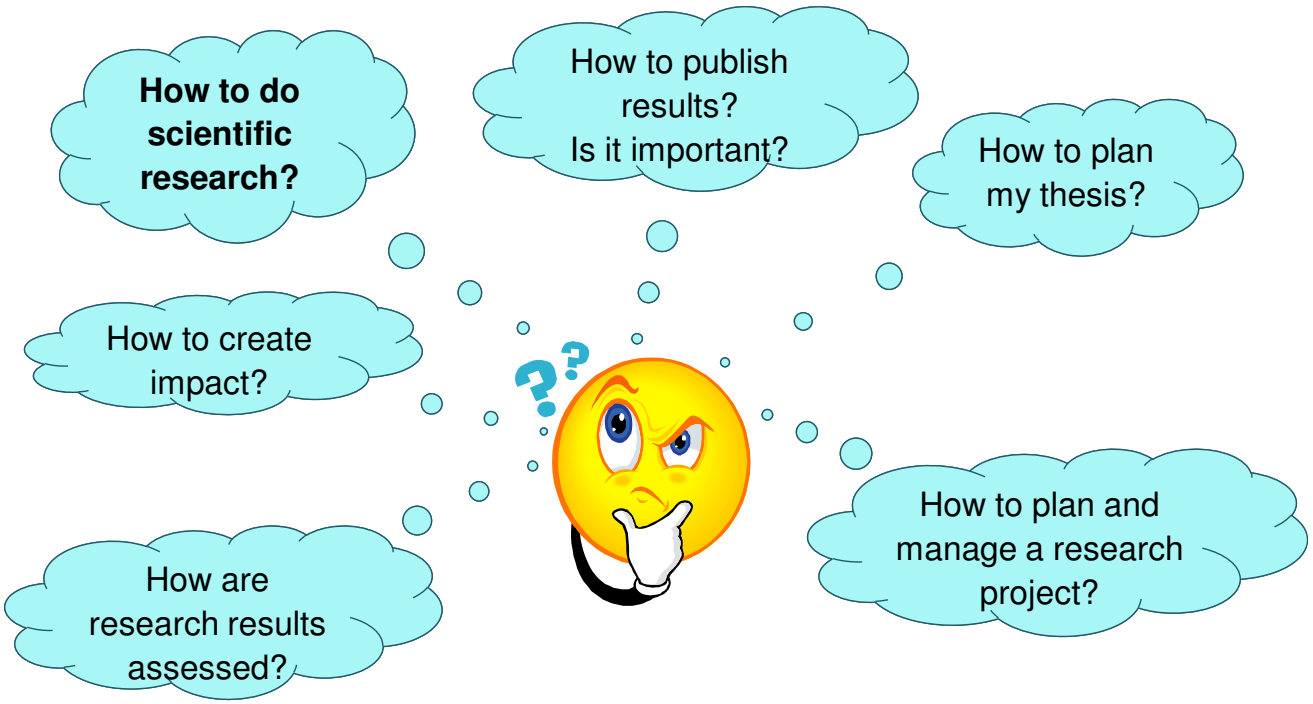
PDEEC - PhD Program on Electrical and Computer Engineering

1. PRELIMINARIES

Are you ready?



Some key questions



Major outcome: PhD Thesis

"The **thesis** must be a substantial original contribution to the knowledge or understanding of any field of study and demonstrate the capacity of the candidate to conceive, design and carry to completion independent research.

The Doctoral candidate should **uncover new knowledge** either by the discovery of new facts, the formulation of theories or the innovative re-interpretation of known data and established ideas.

In particular, **the thesis should demonstrate** that the candidate has:

a) surveyed literature relevant to the thesis;
b) skills in the gathering and analysis of information and report presentation;
c) demonstrated a critical, perceptive and constructive analysis of the subject;
d) carried out original and significant research in the field."

- originality/novelty
- contribution
- significance
- technical soundness
- critical assessment of existing work

[Hong 2006]

PhD Objectives in detail

The PhD degree is awarded to those candidates that show:

a. The capacity for a **systematic understanding** of his / her specialization area.
b. Skills and clear mastery of the **engineering research methods**.
c. Autonomous capacity for conceiving, designing, adapting, and realizing significant **research**, as autonomous researcher or member of a team, respecting the usual academic levels of quality, rigor and integrity.
d. Aptitude for **contributing to widen the knowledge frontiers** through the development of a **significant amount of original research** duly accredited by publication in selected international Conferences and or Scientific Journals with peer reviewing.
e. Capacity to **analyze with a critical spirit**, to **evaluate**, and to **synthesize** new and complex ideas in a context of fast technological and socio-organizational change.
f. Capacity to **communicate** with his / her peers and the academic community as well as the society in general, both at national and international levels, regarding his / her specialization area.
g. Capacity to **promote**, both in the academic and professional contexts, the technological, socio-economic and cultural progress under the framework of a knowledge- and collaboration-based society.

[Portuguese Law]

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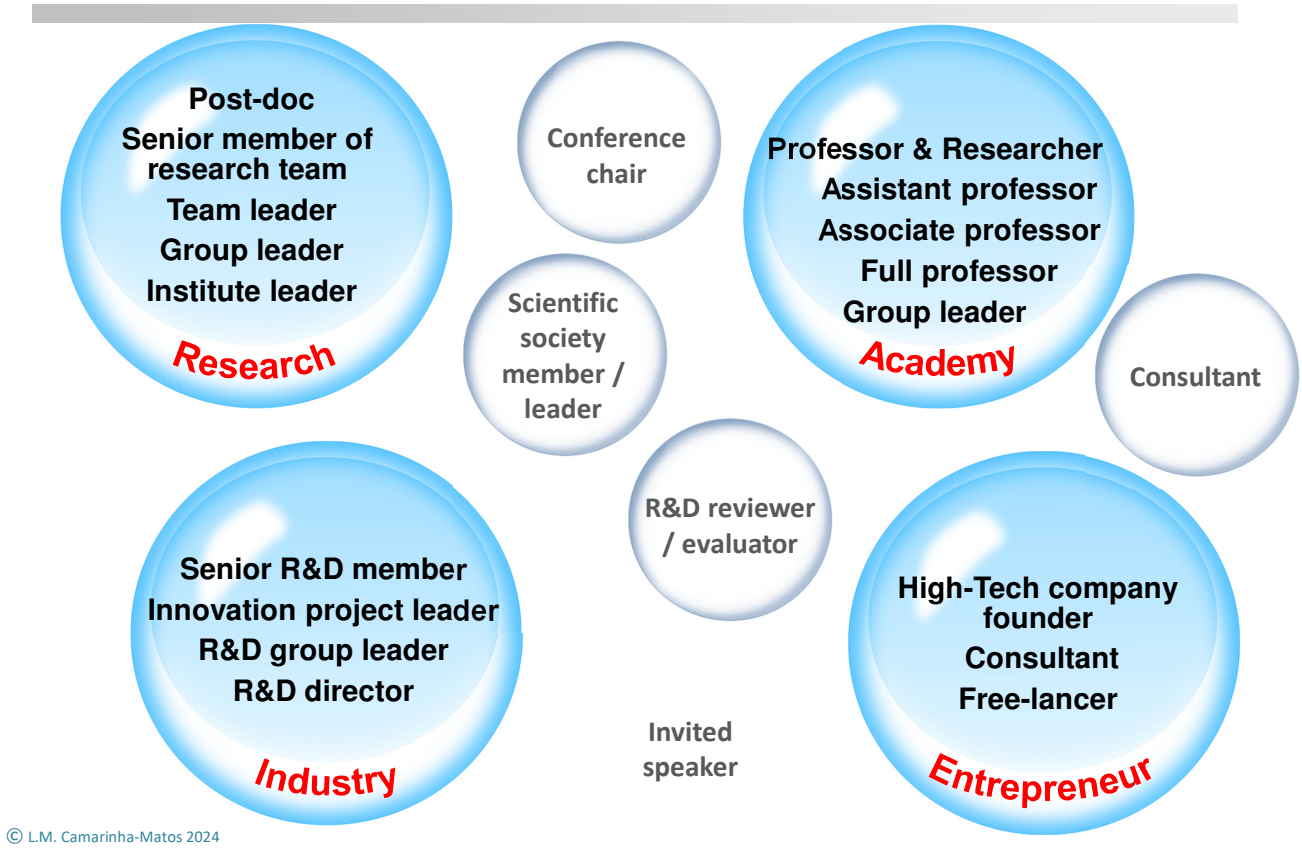
PhD Jobs & more



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Course contents

Unit 1: INTRODUCTION
Objectives for a PhD, base concepts, types of research, relationship with supervisor

Unit 2: RESEARCH METHODS
Overview of research methods, steps of the scientific method, engineering research (design science)

Unit 3: LITERATURE REVISION
Information sources, information search, special sources, synthesis and critics

Unit 4: PUBLICATION OF RESULTS
Writing scientific papers, publication channels, evaluation procedures, citations

Unit 5: THESIS ORGANIZATION AND VALIDATION
Structure, research question, thesis contribution, validation of results

Unit 6: RESEARCH IN COLLABORATION
Types of projects and partnerships, requirements, collaboration spirit and constraints

Unit 7: PROJECT PROPOSAL PREPARATION
General structure of a proposal, typical example

Unit 8: RESEARCH PROJECT MANAGEMENT
Management structure, management principles, tools, risks, reporting

Unit 9: ASSESSMENT OF RESEARCH RESULTS
Phases of research and outcomes, research performance indicators

Unit 10: RESEARCH ETHICS
Ethical issues and behavior, responsible conduct, scientific practices and violation

Unit 11: INTELLECTUAL PROPERTY RIGHTS
Concepts, types, protection mechanisms, rights identification, rights transfer

Unit 12: ROADMAPPING AND FUTURE PLANNING (1)
Future planning objectives and approaches, concept of roadmapping

Unit 13: ROADMAPPING AND FUTURE PLANNING (2)
Roadmapping methodology

Unit 14: PROJECT PROPOSAL PREPARATION - EXAMPLES
Examples in different programs – H2020, ESA

Unit 15: PANEL – PROPOSALS NEGOTIATION EXERCISE

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2. BASE CONCEPTS

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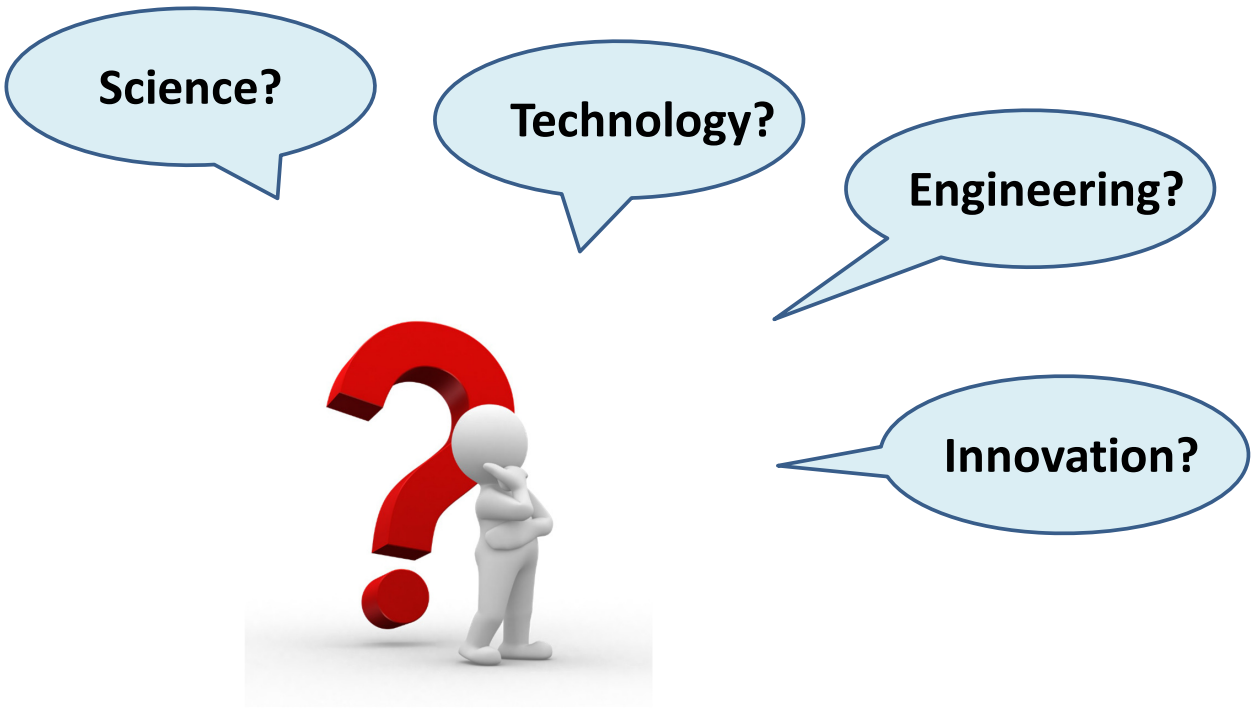
Some common terms



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Science

1. The systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts.
2. The organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation.
3. Any specific branch of this general body of knowledge, such as biology, physics, geology, or astronomy.

Academic Press Dictionary of Science & Technology

Science is an intellectual activity carried on by humans that is designed to discover information about the natural world in which humans live and to discover the ways in which this information can be organized into meaningful patterns.

A primary aim of science is to collect facts (data). An ultimate purpose of science is to discern the order that exists between and amongst the various facts.

Sheldon Gottlieb - http://www.theharbinger.org/articles/rel_sci/gottlieb.html

http://www.gly.uga.edu/railsback/1122science3.html

Technology

Technology is the process by which humans modify nature to meet their needs and wants.

"...the know-how and creative processes that may assist people to utilise tools, resources and systems to solve problems and to enhance control over the natural and made environment in an endeavour to improve the human condition." (UNESCO, 1985).

Often Science and Technology appear together

➔ S&T

referring to advanced technology based on new scientific principles

Engineering

"The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination;

or to construct or operate the same with full cognizance of their design;

or to forecast their behavior under specific operating conditions;

all as respects an intended function, economics of operation and safety to life and property."

American Engineers' Council for Professional Development

Science aims to understand the "why" and "how" of nature.

Engineering seeks to shape the natural world to meet human needs and wants.

Scientists study the world as it is;
engineers create the world that has never been.

Theodore von Kármán

Innovation

The introduction of something new, a new way of doing something, the successful exploitation of new ideas.

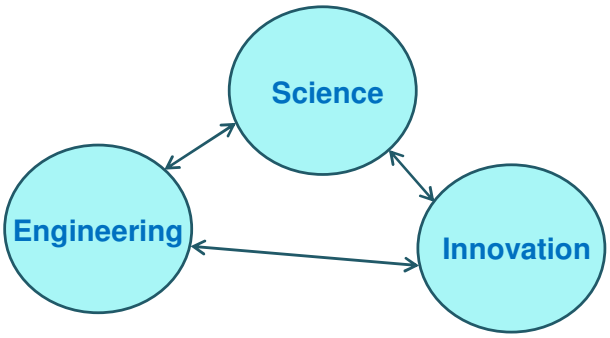
Invention - an idea made manifest
... the first occurrence of an idea for a new product or process

Innovation - ideas applied successfully
... the first attempt to carry it out into practice

- **Incremental innovation - where something is adapted or modified.**
- **Radical innovation - which involves completely new ideas.**

What do we do?

Researchers?
or scientists?



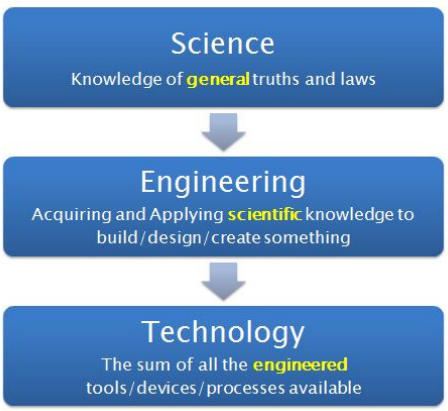
Which relationship?

Do all scientists invent something?

Science vs. technology ?

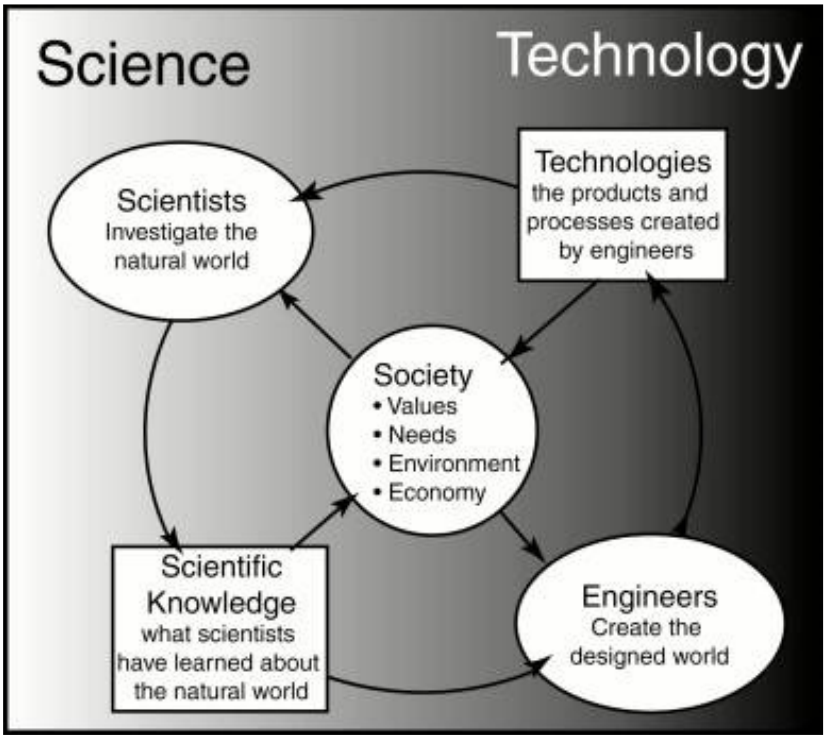
	Science	Technology
Object	unchangeable	changeable
Principle of motion	inside	outside
End	knowing the general	knowing the concrete
Activity	theoria: end in itself	poiesis: end in something else
Method	abstraction	modeling concrete (complex)
Process	conceptualizing	optimizing
Innovation form	discovery	invention
Type of result	law-like statements	rule-like statements
Time perspective	long-term	short-term

[Dodig-Crnkovic, 2002]



https://durofy.com/the-difference-between-science-engineering-and-technology

Science vs. technology ? Another view



http://www.eie.org/overview/science-engineering-technology

Science – some characteristics

- **Science is empirical.**
  Science relies on experience more than authority, common sense, or logic.
- **Science is objective.**
  Objectivity means that same conclusion should be arrived if same observation is made.
- **Science is self-correcting.**
  Because science is empirical, new evidences may contradict the old ones.
- **Science is progressive.**
  Because science is empirical and self-correcting, it is also progressive.
- **Science is tentative.**
  Science never claims to have the whole truth.
  New information may make current knowledge obsolete.
- **Science is parsimonious.**
  Use the simplest explanation to account for a phenomenon.
- **Science is concerned with theory.**
  Develop theory of how something works.

Evolution of science

"Science progresses best when observations force us to alter our preconceptions."

Vera Rubin

"Science progresses when separated things are brought together"

[Berman 2002]

Evolution of science ...

Traditional view - linear and cumulative (follows a direct path from past to present, adding at each point to the achievements of earlier generations)

Kuhn's view:

- **Scientific development is not smooth and linear; instead, it is episodic—that is, different kinds of science occur at different times.**
- **The most significant episodes in the development of a science are *normal science* and *revolutionary science*. *It is also cyclical with these episodes repeating* themselves.**
- **Nor is it cumulative, since revolutionary science typically discards some of the achievements of earlier scientists.**
- **Science does not itself aim at some grand goal such as the Truth; rather individual scientists seek to solve the puzzles they happen to be faced with.**
- **There is no logic of science or fixed scientific method. Instead scientists make discoveries thanks to their training with exemplary solutions to past puzzles**

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Scientific theory, scientific law

Theory

- the *explanation* or a model for a phenomenon
- a conceptual framework that *explains* existing observations and *predicts* new ones
- a logical, time tested *explanation* for events that occur in nature.

Theories not only describe *why* or *how* the phenomenon occurred but also *guide* the way for further research.

A real Scientific Theory tells you what observations are necessary to falsify it.

Theories can really never be completely proven, only disproven. When new evidence comes along, we must modify our theory or at times even get rid of it and start over again.

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Hypothesis

Hypothesis:

An educated guess based upon observation.
It is a rational explanation of a single event or phenomenon based upon what is observed, *but which has not been proved*.

A hypothesis is basically a(n educated) guess.
It is a possible answer to the problem or question.

A hypothesis is testable and falsifiable

A hypothesis is an explanation for a phenomenon which can be tested in some way which ideally either proves or disproves the hypothesis. For the duration of testing, the hypothesis is taken to be true, and the goal of the researcher is to rigorously test the terms of the hypothesis.

When a hypothesis passes the test, it is adopted as a theory (or *thesis*) as it correctly explains a range of phenomena but it *can*, at any time, be falsified by new experimental evidence.

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Thesis

Thesis: A thesis statement declares what you believe and what you have proved.

"a position or proposition that a person (as a candidate for scholastic honors) advances and offers to maintain by argument."

[Webster's 7th New Collegiate Dictionary].

A defense presents evidence for a thesis.

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Paradigm

Paradigm:

"a philosophical and theoretical framework of a scientific school or discipline within which theories, laws, and generalizations and the experiments performed in support of them are formulated; *broadly* : a philosophical or theoretical framework of any kind.

Merriam-Webster Online dictionary

A paradigm is a "excellent example", a model to which others aspire.

Usually, scientists seek to match their work to the paradigm in a way that depends on their seeing similarities between their work and the paradigm

Paradigm Shift is when a significant change happens or scientific revolution

… when researchers encounter anomalies which cannot be explained by the universally accepted paradigm within which scientific progress has thereto been made.

Discipline

A particular branch of scientific knowledge.

A *discipline* has six basic characteristics:

(1) Focus of study
(2) Paradigm
(3) Reference disciplines
(4) Principles and practices
(5) Research agenda
(6) Education
(7) Professionalism

Liles et al. (1995)

Discussion: ***Is Robotics a discipline?***
And Collaborative Networks?
And Cloud Computing?

The emergence of a new discipline

When enough significant anomalies have accrued against a current paradigm, the scientific discipline is thrown into a state of *crisis*, according to Kuhn.

During this crisis, new ideas, perhaps ones previously discarded, are tried.

Eventually a *new* paradigm is formed, which gains its own new followers, and an intellectual "battle" takes place between the followers of the new paradigm and the hold-outs of the old paradigm.

The new paradigm may lead to a new discipline.

https://www.sfu.ca/educ867/htm/paradigm.htm

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Research

Research is the systematic process of collecting and analyzing information to increase our understanding of a phenomenon under study.

a. The systematic investigation into and study of materials, sources, etc., in order to establish facts and reach new conclusions.
b. An endeavour to discover new or collate old facts etc. by the scientific study of a subject or by a course of critical investigation.

[Oxford Concise Dictionary]

Research encompasses activities that increase the sum of human knowledge.

[OECD Definition]

The word *research* is composed of two syllables, *re* and *search*.
The dictionary defines the former as a prefix meaning again, anew or over again and the latter as a verb meaning to examine closely and carefully, to test and try, or to probe.

Together they form a noun describing a careful, systematic, patient study and investigation in some field of knowledge, undertaken to establish facts or principles.

[Grinnel, 1993]

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Research ...

*The **systematic** process of collecting and analyzing information (data) in order to discover new knowledge or expand and verify the existing one (e.g. theory - law)*

The research process must :

1. **Be undertaken within a framework of a set of philosophies.**
2. **Use procedures, methods and techniques that have been tested for their validity and reliability.**
3. **Be designed to be unbiased and objective.**

When you write a paper you (often) have to explain the research method

Subjectivity: an integral part of your way of thinking that is conditioned by your educational background, discipline, philosophy, experience and skills.

Bias: a deliberate attempt to either conceal or highlight something.

[Kumar 2005]

Research and Development – R&D

Research and experimental development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

[OECD Definition]

In the world of business, research and development is the phase in a product's life that might be considered the product's 'conception':

- *research* phase: basic science must exist to support the product's viability, and if the science is lacking, it must be discovered.
- *development* phase: if the science exists, then turning it into a useful product.

Research characteristics

To qualify as research the process must have the following characteristics:

- **Controlled** – in exploring causality in relation to two variables, the study must be set in a way to minimise the effects of other factors affecting the relationship.
- **Rigorous** – be scrupulous in ensuring that the procedures followed to find answers to questions are relevant, appropriate and justified.
- **Systematic** – the procedures adopted to undertake an investigation follow a certain logical sequence ... Different steps cannot be taken in a hazardous way.
- **Valid and verifiable** – whatever is concluded on the basis of the findings must be correct and can be verified by the researcher and others.
- **Empirical** – any conclusions drawn are based upon hard evidence gathered from information collected from real-life experiences or observations.
- **Critical** – critical scrutiny of the procedures used and the methods employed.

[Kumar 2005]

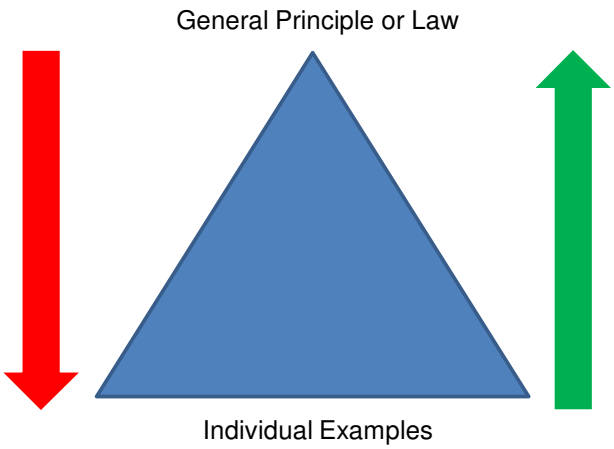
Principles

Deduction vs. Induction

DEDUCTION

• Begins with a general principle and reasons to particulars (individual examples)
•Type of reasoning most commonly associated with geometric proofs

❑ Advantage: If all the terms are perfectly defined it produces absolute certainty
❑ Disadvantage: Difficult to find circumstances in which all terms and principles can be defined perfectly



INDUCTION

•Begins with observation of individual examples and reasons to form general principles about their relationships
•Type of reasoning most commonly associated with experimentation
❑ Advantage: Relatively easy to do – just observe the world
❑ Disadvantage: Can never be absolutely certain one has observed ALL particulars

[Hadbavny , 2008]

Concept, Indicator or Variable

Concepts are mental images or perceptions
➔ their meanings vary from individual to individual.

Variables or indicators are measurable (with varying degrees of accuracy).

***Measurability* is the main difference between a concept and a variable.**

In order to assess research results it is important for the concepts to be converted into variables or indicators as they can be subjected to measurement.

***Operationalisation* of a concept => how it will be measured.**

[Kumar 2005]

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3. SCIENTIFIC RESEARCH

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Brief history landmarks

Aristotle

(384 BC - 322 BC)

Aristotle, more than any other thinker, determined the orientation and the content of Western intellectual history.
He was the author of a philosophical and scientific system that through the centuries became the support and vehicle for both medieval Christian and Islamic scholastic thought: until the end of the 17th century, Western culture was Aristotelian.

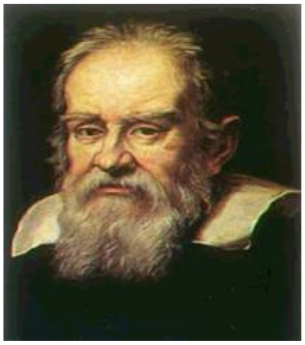
Aristotle and his contemporaries believed that all problems could be solved by thinking about them.

Sometimes this worked, other times it did not.
For example, Aristotle thought that heavy objects would fall faster than lighter ones.

What did Aristotle not do?
He never tested his ideas!
The world would have to wait almost 2000 years for that to happen.

Brief history landmarks ...

Galileo Galilei



(1564-1642 AD)

Often considered the first true scientist.

Why?
Because he actually did the experiment !

Aristotle thought that heavy objects fall faster than lighter ones.

So Galileo asked, “How much faster?”
He sent students up to the top of a building and had them drop a heavy ball and a lighter one off at the same time. He had other students waiting below to measure the difference in time between the two hitting the ground.

Much to everyone’s surprise both balls hit the ground at about the same time!
This shows that it is much preferred to test your ideas rather than merely think about them.

.... Simulation is not enough either !

Brief history landmarks ...

Ibn al-Haytham

(Alhacen or Alhazen)

(965 - 1039 AD)

Born	c. 965 Basra, Buyid Emirate
Died	c. 1040 (aged 75) Cairo, Fatimid Caliphate
Residence	•Basra, Cairo
Fields	•Optics, Astronomy, Mathematics

Perhaps not so known in the West ....

He is considered the pioneer of the modern scientific method and the originator of the experimental nature of physics and science

... long before Galileo!

He made significant improvements in optics, physical science, and the scientific method which influenced the development of science for over five hundred years after his death.

Ibn al-Haytham's work on optics is credited with contributing a new emphasis on experiment.

Example:
Ibn al-Haytham proved that light travels in straight lines using the scientific method.

Types of research – *Viewpoint of application*

■ Pure, basic, or fundamental research

- Driven by the **scientist's curiosity** or interest in a scientific question.
- Involves development and testing theories and hypothesis that are intellectually challenging to the researcher but may or may not have practical application at the present time or in the future.
- ...Frequently involves very abstract and specialized concepts

■ Applied research

- Designed to **solve practical problems** of the real world, rather than to acquire knowledge for knowledge's sake.
- Often involves the use of some technology in the development of new processes or systems.
- Frequently linked to R&D

What distinguishes applied research from engineering?

Types of research – *Viewpoint of application ...*

Another classification:

■ **Pure basic research** is experimental and theoretical work undertaken to acquire new knowledge without looking for long-term benefits other than the advancement of knowledge.

■ **Strategic basic research** is experimental and theoretical work undertaken to acquire new knowledge directed into specified broad areas in the expectation of useful discoveries. It provides the broad base of knowledge necessary for the solution of recognized practical problems.

■ **Applied research** is original work undertaken primarily to acquire new knowledge with a specific application in view. It is undertaken either to determine possible uses for the findings of basic research or to determine new ways of achieving some specific and predetermined objectives.

■ **Experimental development** is systematic work, using existing knowledge gained from research or practical experience, that is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

https://www.abs.gov.au/ausstats/abs@.nsf/66f306f503e529a5ca25697e0017661f/22E4C184CA111129CA25697E0018FD78?opendocument

Types of research – *Viewpoint of objectives*

- **Descriptive research** — Attempts to describe systematically a situation, problem, phenomenon, service, etc. E.g. Structure of a system, organization, etc.
- **Correlational research** — To discover or establish the existence of a relationship / association / interdependence between two or more aspects of a situation. E.g. What is the relationship / impact / effect of <this> in <that>.
- **Explanatory research** — Attempts to clarify or explain why and how there is a relationship between two aspects of a situation or phenomenon.
- **Exploratory research** — When the objective is to explore an area where little is known or to investigate the possibility of launching a particular research study.

[Kumar, 2005]

Another perspective:

Descriptive (of the significant aspects of the research domain)
Explicative (of the behavior of a phenomenon)
Predictive (of the future)
Prescriptive (involving, in addition to prediction, prescription and application of norms and processes)

Types of research – *Viewpoint of inquiry mode*

(Strategies of inquiry)

- **Quantitative strategies** (or structured approach) — **... to determine the extent of a problem, issue, or phenomenon**
  - **Survey research** ... Studies samples
  - **Experimental research** ... To determine impacts or influences
- **Qualitative strategies** (or unstructured approach) — **... to explore the nature of a problem, issue, or phenomenon**
  - **Ethnography** ... Studies an intact "cultural group" in a natural setting over a prolonged period of time
  - **Grounded theory** ... Derives a general, abstract theory of a process, action, or interaction grounded in the views of participants
  - **Case studies** ... Exploring in depth an event, activity, process or entity
  - **Phenomenological research** ... Trying to understand the meaning of a phenomenon as perceived by the actors that "lived it"
  - **Narrative research** ... Based on the analysis of stories / narratives

[Creswell, 2009]

Types of research – *Viewpoint of inquiry mode ...*

Mixed strategies

Sequential mixed methods
- Elaborate on / or expand the findings of one method with another method

Concurrent mixed methods
- Merges quantitative and qualitative data in order to reach a comprehensive analysis of the research problem

Transformative mixed methods
- Uses a theoretical lens to determine topics of interest and the methods to apply

[Creswell, 2009]

Often researchers engaged in one type despise those involved in another type ... !!!

Some "philosophies"

Assumptions of Post - Positivism

Absolute truth can never be found.
Research is a process of making claims and then testing, refining or abandoning some of them for other claims more strongly warranted.
Data, evidence and rational considerations shape knowledge.
Research seeks to develop relevant, true statements that can serve to explain the situation that is of concern or that describe the causal relationship of interest.
Researchers must examine their methods and conclusions and control or limit bias.

Assumptions of Interpretivism

Meanings are constructed by humans as they engage with the world they are interpreting.
Humans make sense of the world based on their historical and social perspective. They seek to understand the context and then make an interpretation of what they find which is shaped by their own experiences and backgrounds.
The basic generation of meaning is always social.

[Opfer]

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Some “philosophies” …

Assumptions of Participatory

Participatory research is recursive and dialectical and is focused on bring about change in practices.
Begins with a stance about the problems in society.
It is emancipatory.
It is inquiry completed with others rather than on or to others.
The research process is cyclical.

Assumptions of Pragmatism

Is not committed to any one system of philosophy or reality.
Individual researchers have freedom of choice to select procedures that best meet their needs.
Pragmatists do not see the world as an absolute unity.
Truth is what works at the time.
We need to stop asking questions about reality and the laws of nature and start solving problems.

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4. PRACTICAL ISSUES

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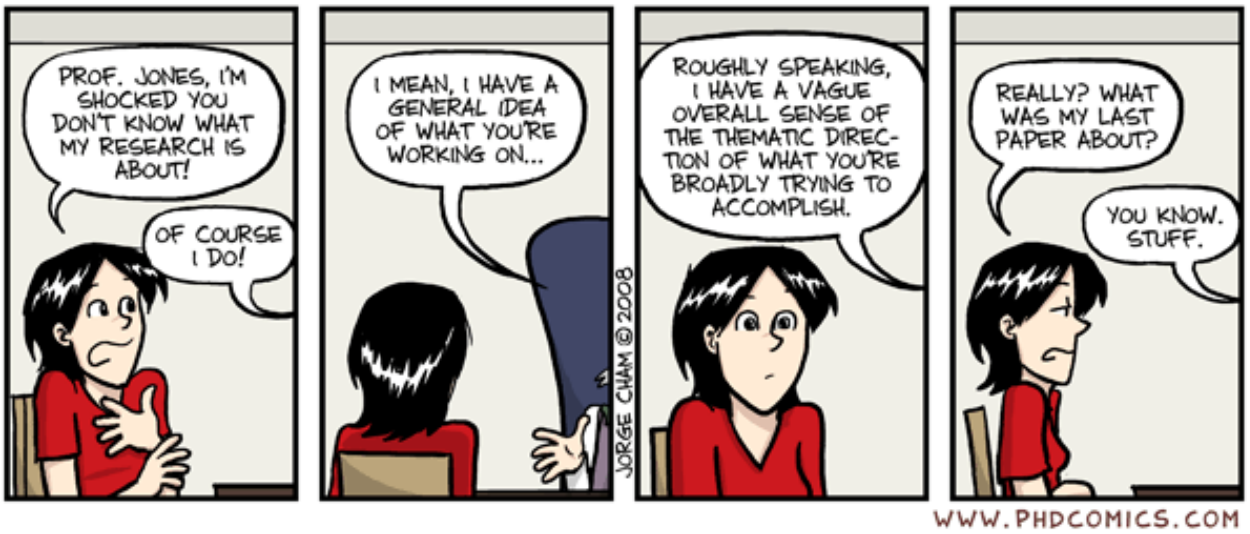
You and your supervisor ?



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Relationship with supervisor

- Scientific & methodological guidance
- Suggestions and assessment
- Reassurance, support
- Polishing technical writting
- Resources, hosting project
- Contacts, social networking
- Facilitator to access scientific channels
- Experience
- *Mentor, friend, confidante, adviser and also a voice of reason*
- ...

WIN-WIN

SUPERVISOR

PhD STUDENT

- Hard work, enthusiasm
- Labor resource (for projects, etc.)
- Generation of experimental results
- Contribution to publications
- Contribution to project proposals (at a later stage)
- ...

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Choosing a supervisor

Before jumping into the unknown,
remember that your supervisor will be your guide

... One of the most critical decisions ...

- **Is an expert in the area you selected ?**
- **Is internationally recognized in the area ?**
- **Is well connected in the international scientific arena ?**
- **Is willing and able to promote your work at conferences and the like?**
- **Is active (research, publications) ?**
- **Has previous supervision experience ?**
- **Is interested in the topic you selected ?**
- **Can provide research facilities ?**
- **Is willing to fight the *system* for you ?**
- **Will you be integrated in a group ?**
- **Do you want co-supervision?**

- **Personal chemistry ?**

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How does a researcher work?

Above all …
you need strong psychological resistance !

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Emotional factors

- Research is **hard**.
- All research involves **risk**.... If your project can't fail, it is development, not research.
- Along your career, you'll accumulate a lot of **failures**.
  ... Even the (apparently) successful researchers accumulate (many) failures.
- Research always takes much, much **longer** than it initially seems.
- Crucial to success is making your research **part of your** everyday **life**.
  ... think about your research in background mode all the time.
- You'll find that your **rate of progress** seems to vary a lot ... Sometimes no progress at all. At other times you get stuck and feel like you can't do anything for a long time.
  Setting your sights too high leads to paralysis.
  Work on a sub-problem to get back into the flow.
  It's hard to get started working in the morning, easy to keep going once you've started ➔Leave something easy or fun unfinished in the evening that you can start with in the morning.
- **Fear** of failure can make work hard and discourage.

Based on MIT: www.cs.indiana.edu/mit.research.how.to/section3.13.html

■ **You are aiming a PhD, not a Nobel prize (at this time) !**

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

How should you work?

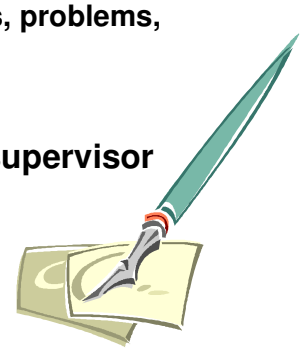
SOME HINTS FOR A PhD CANDIDATE:

- **Work regularly ... It helps keeping things in mind.**
- **Allocate large blocks of time for research**
  ... Task switching takes time
  ... Do something significant in each session
- **Maintain a research notebook / journal of day-to-day thoughts.**
  Read it periodically.
- **Keep an updated task list ... and focus on accomplishing something each session.**
- **Periodically write a few pages (summaries, accomplishments, problems, speculations) on a subset of your work.**

A good practice: send a 1-page summary, weekly, to your supervisor

IMPORTANT NOTICE

- What you have achieved during the week
(not the activities but rather the achievements)
- What you plan to do during next week.



Further notes

Creswell, J. W. (2009). Research Design: Qualitative, Quantitative, and Mixed Method Approaches. SAGE.

Dodig-Crnkovic, G. (2002). COMPUTER SCIENCE IN A THEORY OF SCIENCE DISCOURSE. Master Thesis in Computer Science. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=664AECAC339E0C2AD06D8BAF52BCDD0E?doi=10.1.1.12.5766&rep=rep1&type=pdf

Hong, L. Y. (2006). RESEARCH METHODS IN ENGINEERING AND SCIENCE. http://www.wabri.org.au/postgrads/documents/RM%20sci_eng_notes/Eng_Leung.pdf

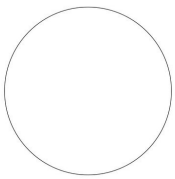
Kumar, R. (2005). Research methodology – A step-by-step guide for beginners. SAGE.

Liles, D.; Johnson, M.; Meade, L.; Underdown, D. (1995). Enterprise Engineering: A discipline?, Society for Enterprise Engineering (SEE) Conference, Orlando, FL, http://www.webs.twsu.edu/enteng/ENTENG1.html

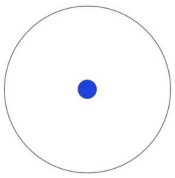
The illustrated guide to a Ph.D.

https://matt.might.net/articles/phd-school-in-pictures/

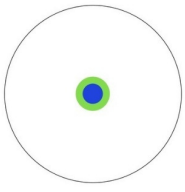
Imagine a circle that contains all of human knowledge:



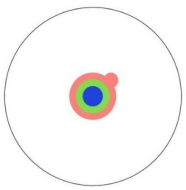
By the time you finish elementary school, you know a little:



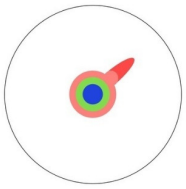
By the time you finish high school, you know a bit more:



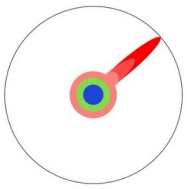
With a bachelor's degree, you gain a specialty:



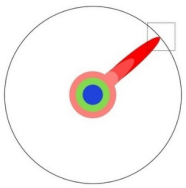
A master's degree deepens that specialty:



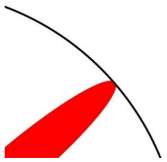
Reading research papers takes you to the edge of human knowledge:



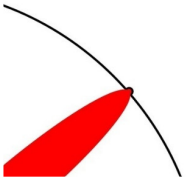
Once you're at the boundary, you focus:



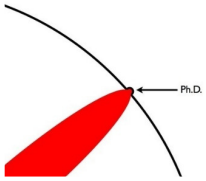
You push at the boundary for a few years:



Until one day, the boundary gives way:



And, that dent you've made is called a **Ph.D.**:



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