Ph.D. and Research: Are they Synonymous

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Understanding the difference between Ph.D. and Research

- **Ph.D. Degree**: is where you learn how to do research.

- **Research**: Experiment or modeling, your aim is to reveal **THE TRUTH, NOT SOME DEGREE** or publication. Those you get incidentally.

Both of these requires,

- **An analytical mind**
- **Faith in scientific method and not to compromise with that**.
Besides helping you in getting publications, degree, and a job, what do research teach you in life?

- Skill of planning.
- Hope.
- Patience.
- Art of management.
- Broad outlook.
- Pleasure of getting to a truth.
Can/should research methodology / experimental skills be taught by giving lectures?

No, because
1. These are arts and experiences.
2. They are diverse.

Yes, because
1. Even art has a grammar.
2. There are commonalities.
3. It serves as a guidance to the research scholar.
Jokes about research

- “When you do not know what you are doing, do it neatly.”
- “Team work is essential. It always allows you to blame someone else.”
- “If reproducibility may be a problem, conduct the test only once.”
- “If a straight line fit is required, obtain only two data points.”
- “If an experiment works, something has gone wrong.”
- “If enough data is collected, anything may be proven by statistical methods.”
What is important in research?

- The method is not more important than the problem unless you are developing the method itself.

- Always look for novelty in research.

- Analysis is important to prove an idea but the idea is more important than that.

- Hence spend more time at your table than computer terminal or laboratory.
Theoretical

Experimental
Why should we do experiments at all?

- To know the truth.
- To get insight into the physics.
- To determine the unknown factors responsible.
- To test a theory.
- To facilitate simulation/modeling work.

(Example: Use of experimentally determined unknown constants in turbulence modeling)
Defining aim/objective of the experiments (but remain flexible).

Scope of the work (research is infinite but requirement of a research degree is limited – Dr. Sahoo).

Defining the parameters you are looking at.

Broadly decide the approach (e.g., theoretical, experimental, both, numerical).
Design

- Working out the best possible design with all the constraints you have got.

- Inputs from literature and suggestions from the technicians.

- Changing design at a later stage may be very costly in terms of time and money.

- In case of a new design, trial and error method is the only option. (Eg., Heater-thermocouple design.)
Fabrication

- Making thorough enquiries to find a potential fabricator/supplier with good expertise in the relevant area.

- Following proper order in steps/stages involved in fabrication with parallel efforts so as to minimize the time.

- Maintaining the healthy relationship with the fabricator to get the best out of him.

- Respect the technicians, you can learn from them what you cannot learn from your Professor.
While choosing the instruments, attention has to be paid to:

- **Accuracy**
- **Precision**
- **Range**
- **Response time**
- **Least count**
- **Cost**

Points to remember in instrumentation:

1. **High Accuracy** and **Low Precision**
2. **High Accuracy** and **High Precision**
3. **Low Accuracy** and **High Precision**
4. **Low Accuracy** and **Low Precision**

![Diagram showing accuracy and precision combinations](image)
Calibration and error analysis

- Principles of transducers.
- Calibration of the equipment with a standard device.
- Systematic errors and random errors (Lord Rayleigh).
- Number of variables and error estimation principle statistically.
- A realistic approach towards accuracy.

Validation of the experimental set-up and results with benchmark results from literature.
Running the experiments

- Before running the experiments, make sure that all the components/connections/loops/circuits are proper.

- Make a measurement protocol with date and specific conditions. Do not forget to specify atmospheric conditions if they are important.

- Carry out the experiments according to the laid-out procedure.

- Monitor all the components and devices for possible fluctuations/deviations from the set values while experiment is in progress.

- After few experiments try to explain your results and then proceed further.
Safety measures

**Do not compromise on safety aspect.** All the possible precautions are to be taken. Some of them are:

- Goggles/Masks/Helmets/Gloves/Apron while doing experiments with poisonous/hazardous chemicals, applying silicone sealants, dealing with extremely fine powder.

- Safety valves/safety meshes while doing high pressure glass vessel experiments. (Prof. RN)

- Sound guards in case of wind tunnel experiments. (Prof at ME).

- Utmost care (shock-proof gloves and shoes) while doing high voltage experiments.

- Fire extinguisher a must for all experiments.

- Care and ethical issues in handling biological samples and living animals.
Analysis of the experimental results

- Sufficient number of data points.
  
  "Between three data points, any curved profile can be fit"

- Consistency and repeatability (precision).

- Accuracy
Repeatability and Accuracy
Look at the results in unbiased way or without any prejudice.

(eg., Nano-boiling)

Keen observation of the data.

(eg., Becquerel)

Experiments with frogs (Galvany), etc.

Honesty- Don’t ‘MOVE’ your experimental points so as to match with theory. Leave them as they are. An explanation may be there. (Positron at Saha Institute, Fynmann)

Changing the course of the experiments depending on the results.
Why mathematical modeling?

- To understand the behavior of systems.
- To obtain optimal designs/operational conditions.
- To analyse physical systems where experiments are not possible (Nuclear / Rockets / Astronomy etc.).
- To obtain variation of parameters in details like the complete field (flow/thermal/electric).
Modeling Methods

- Order-of-magnitude & Dimensional analysis.
- Overall system level models (Steady/ transient) Lumped/Assembly (Fuel cells).
- Simplified 1-D/ 2-D models.
- Fully comprehensive transient, 3-D models.
- Heuristic /statistical models.
Example - understanding phenomena

- Failure of Takoma bridge.
- The vortex shedding frequency of wind flow matched with the natural frequency of the suspension bridge.
- Failure occurred by torsional vibrations - resonance with vortex shedding.
- It is possible to carry out a detailed dynamic analysis of the bridge structure using FEM and the natural frequencies can be predicted.
Renowned British scientist G.I. Taylor was told by the British government about the development of the atomic bomb and was asked to think about the mechanical effect produced by such an explosion. Taylor using dimensional analysis gave the radius of the shock wave at any time $t$ as,

$$ R = C \left( \frac{E}{\rho} \right)^{1/5} t^{2/5} $$
Modelling of biological heat transfer

\[
\rho c \frac{\partial T}{\partial t} + \nabla \cdot (-k \nabla T) = Q_{\text{blood}} + Q_{\text{metabolic}} + Q_{\text{source}}
\]

\[
Q_{\text{blood}} = \left( \rho_b w_b c_b (T_b - T) \right)
\]

\[
Q_{\text{laser}} = \alpha I_0 \exp\left[-\frac{r^2}{2\sigma(0) \exp(\beta z_c)}\right] \exp[-(\alpha + \beta)(z_s - c_d)] \exp[-(\alpha_s + \beta_s)(z_s)] \exp[-(\alpha_t + \beta_t)z_d]
\]

\[
P(H, r_n, T, \text{type of nanoparticle}) = \frac{c^2 N\mu_0^2 V_H^2 H^2 \sigma(r_n)^2 \pi}{M_n k_B T \tau_0 \exp\left[\frac{2E_B}{T}\right]}
\]
Thermal profile of tumor (laser ablation): experimental and model
Before you begin modeling.....

- Understand the limitations – “as the model so are the solutions”.

- Model can simulate only the physics that you have considered through mathematical equations (channel vs micro-channel and surface tension).

- Beware of your assumptions and boundary conditions (continuum/no-slip/constant property etc.).

- Cannot replace experiments fully. Can only reduce the number of experiments.

- Always look for proper validation and accuracy.
All the results are to be documented irrespective of the nature/use as these may be of use later.

(eg. Pressure drop - Prabhakar).

Communicating the results to journals/conferences is not just for publication, but also to get comments/ suggestions/ reviews from international community which will be of much help in your research.
Pride and modesty.

Avoid frustration have patience and perseverance. Never give up (Edison).

Be relaxed and appreciate difficulties (Heater).

Stay focused (Arjuna).

Be flexible in approach (Frank and me - temp. measurement).

Be honest (Fermi / IISc. Scholar).

Always have a mental picture of your experiments going right (even in dream or toilet).

Avoid postponement.
Some more

- Discipline, sincerity, punctuality but freedom and informality promotes creativity.
- Interaction with your friends – Help each other without jealousy/envy.
- Be fully prepared for the unforeseen problems.
- Requires few months to few years of preparation to get results in no time.
It is in journey or in efforts that true satisfaction/happiness lies, not in reaching goal.

Thank you
Questions?