Research Methods

Though this be madness, yet there is method in't — *Hamlet*

Research Methods - Barbara Russo

SwSE - Software and Systems Engineering

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Goal

*Learn the **key research paradigms** in Computer Science and apply one of them to a **research problem***

What you will learn

- Get an understanding of what research is
- Learn about the methods used in research
- How to apply one of the research paradigm to a real problem

Careful!

- Learning research paradigms it is just the starting point

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- Learning research paradigms it is just the starting point **you must create your own style**

What is Research?

Research

- **Diligent and systematic inquiry or investigation** in an area, with the objective of discovering or revising facts, theories, applications. The goal is to **discover and disseminate new knowledge**

[Merriam-Webster]

Terminology

- **Research Method** refers to the manner in which a particular research project is undertaken. There is **no unique/universal** research method (e.g., math proof)
- **Research Technique** refers to a specific means, with which to perform research (e.g., proof by contradiction)
- **Research Methodology** refers to the study of research methods and devise which of them can be used in a specific context

Major types of research

- **Basic research** aims at increasing scientific knowledge
- **Applied research** aims at using basic research

Pure vs. applied

- **Basic (or pure) research**
  - Not motivated by existing needs
  - Understanding nature, developing algorithms
  - Produces general theories
- **Applied research**
  - Anticipates usage by others
  - Suggests social/economic benefits
  - Produces practical results

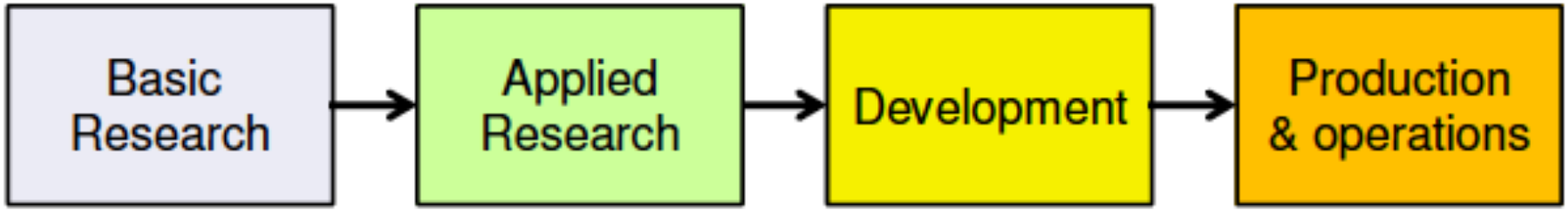
Basic or applied research
Debate: Which drives which?

Science: The Endless Frontier (Bush 1945)

- Roosevelt's Science Advisor
  - Separate basic from applied research
  - Academic basic research urges strong governmental support
  - **Applied research executes the basic one**

Science: The Endless Frontier (Bush 1945)

- Liner model for science:

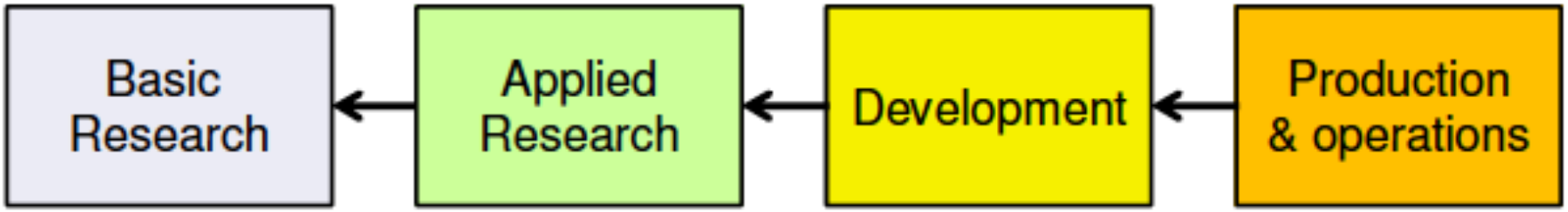


Pros & Cons

- **Free** from pressure
- Basic research may choose the **non-relevant problems**
- Basic researchers **do not talk** with industry there is no technological transfer to be made

Reverse linear model (Bell Labs 60ties)

- Commercial success: **get industry to set the research agenda** based on problems that they face



Example 1

Inventor/s cientist	Technological source	Years	Scientific field developed
Toricelli	improved pump – explored the weight of the atmosphere	1600s	Atmospheric/pressure science/barometer
Watt/Carnot	steam engines	1830s	Thermodynamics
Pasteur	wine industry/ fermentation	1850s	Bacteriology/germ theories
Perkin /Hoffman	Synthesis of mauve, first aniline dye	1870s	Organic chemistry
Wilm	Bessemer process; age-hardening of duraluminum	1850-1900s	Metallurgy/ materials science

Example 2

Inventor/ scientist	Technological source	Years	Scientific field developed
Davisson	vacuum tubes – patterns of emission from nickel crystal due to electrons	1920s	Wave nature of matter/ Nobel prize 1937
Jansky/ Bell labs	radio noise	1932	Radio astronomy (star noise)
Townes/ Bell labs	Laser technology for optic fiber cables	1950s	Optics resurgence
Shockley	Transistor/ semiconductor	1948	Solid state physics

Pros & cons

- Listen to industry problems & solve them -> technology transfer is easy
- **But some research might not be driven by industrial needs**

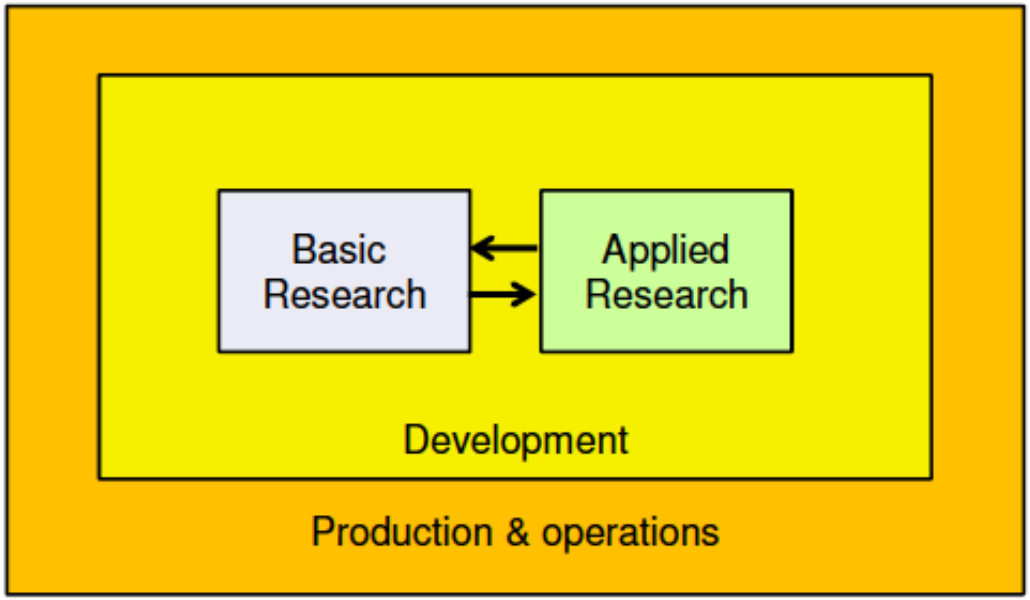
High Impact Research: Blending Basic and Applied Methods —Ben Shneiderman 2013

High impact research

- **Address National / International priorities**
  - Basic and applied questions
  - Theoretical & practical outcomes
  - Curiosity-driven & mission-driven
- **Multiple methods / disciplines**
- Interventions in **working large-scale systems**
  - Repeated case studies support or falsify hypotheses

Bornfenbrenner's Ecological Model (1979)

- Basic and applied research collaboratively interact embedded in Development and Production environment
- Low barriers to technology transfer



Shneiderman's scientific method

- Start with a practical problem & existing theory
- Write a lucid & testable Hypothesis
- Alter a small number of independent variables (treatment)
- Select & assign subjects
- Control other variables
- Measure a small number of dependent variables
- Apply statistical test
- Solve problem, refine theory, produce guidance for future researchers

An example

- **Start with a practical problem & existing theory**
- *Is the iPhone XS user friendly?*
- **Write a lucid & testable Hypothesis**
- *Notifications lower user friendliness*
- *When a notification appears, the application I am using interrupts and resumes to its previous state afterwords*

Hypotheses formulation

An example

- **Alter a small number of independent variables (treatment)**
- *Independent variable: notification occurrence (Boolean); (others can be interruption time or type of interruption)*
- **Select & assign subjects**
- *Two groups of users of iPhone XS: one experiences notifications and one does not experience notifications*
- **Control other variables**
- *Other types of interruptions (cable plugin and out or wi-fi connectivity)*

Design of the study

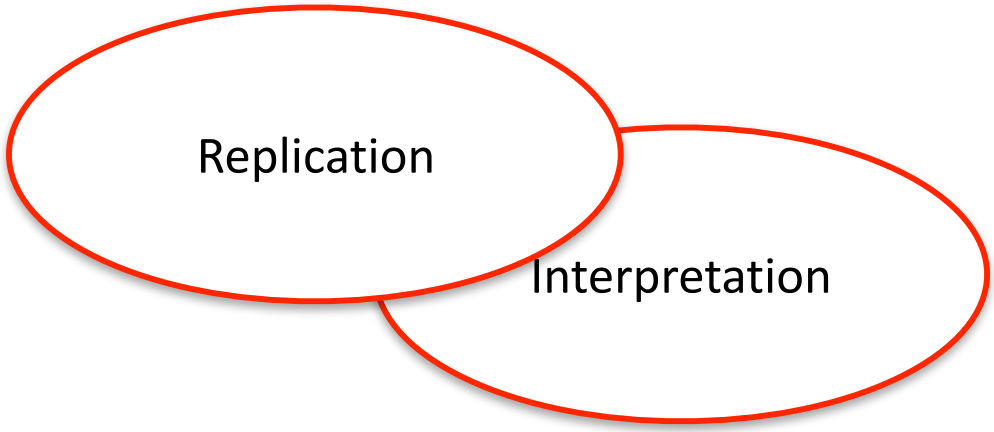
An example

- **Measure small number of dependent variables**
- *Dependent variable: user friendliness*
- *Interview users on user friendliness (Rate 1-5)*
- **Apply statistical test**
- *Measure the mean of user friendliness in the group that experienced notifications and in the group that did not experience notifications. Analysis of variance (ANOVA)*

Analysis

An example

- Solve problem, refine theory, produce guidance for future researchers
- *Filter notifications, extend the study to a different sample, analyse the problem by type of notification or interruption*



Exercise

- Is the iPhone XS user friendly?
- Repeat the Shneiderman' method for the testable hypothesis:
- User friendliness of iPhone XS depends on technical skills of the users
  - *Subjects that have already used a smartphone consider the iPhone XS user friendly*

Replication