



## High Impact Research: Blending Basic and Applied Methods

Ben Shneiderman [ben@cs.umd.edu](mailto:ben@cs.umd.edu) @benbendc

Founding Director (1983-2000), Human-Computer Interaction Lab  
Professor, Department of Computer Science  
Member, Institute for Advanced Computer Studies



Interdisciplinary research community  
- Computer Science & Info Studies  
- Psych, Socio, Poli Sci & MITH

([www.cs.umd.edu/hcil](http://www.cs.umd.edu/hcil))



## Design Issues

- Input devices & strategies
  - Keyboards, pointing devices, voice
  - Direct manipulation
  - Menus, forms, commands
- Output devices & formats
  - Screens, windows, color, sound
  - Text, tables, graphics
  - Instructions, messages, help
- Collaboration & Social Media
- Help, tutorials, training
- Search • Visualization



[www.awl.com/DTUI](http://www.awl.com/DTUI)

**Fifth Edition: 2010**



## HCI Pride: Serving 5B Users

### Mobile, desktop, web, cloud

- **Diverse users:** novice/expert, young/old, literate/illiterate, abled/disabled, cultural, ethnic & linguistic diversity, gender, personality, skills, motivation, ...
- **Diverse applications:** E-commerce, law, health/wellness, education, creative arts, community relationships, politics, IT4ID, policy negotiation, mediation, peace studies, ...
- **Diverse interfaces:** Ubiquitous, pervasive, embedded, tangible, invisible, multimodal, immersive/augmented/virtual, ambient, social, affective, empathic, persuasive, ...



## Information Visualization: Data Types

SciViz

- **1-D Linear** Document Lens, SeeSoft, Info Mural
- **2-D Map** GIS, ArcView, PageMaker, Medical imagery
- **3-D World** CAD, Medical, Molecules, Architecture

InfoViz

- **Multi-Var** Spotfire, Tableau, Qliktech, Visual Insight
- **Temporal** LifeLines, TimeSearcher, Palantir, DataMontage
- **Tree** Cone/Cam/Hyperbolic, SpaceTree, Treemap
- **Network** Pajek, UCINet, NodeXL, Gephi, Tom Sawyer

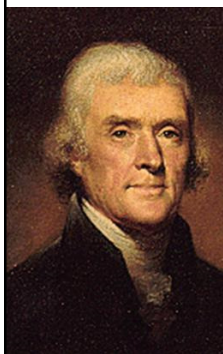
infosthetics.com  
flowingdata.com  
visual.ly

visualcomplexity.com  
perceptualedge.com  
visualizing.org

eagereyes.org  
datakind.org  
infovis.org



## Jefferson's Mission Statement (1804)



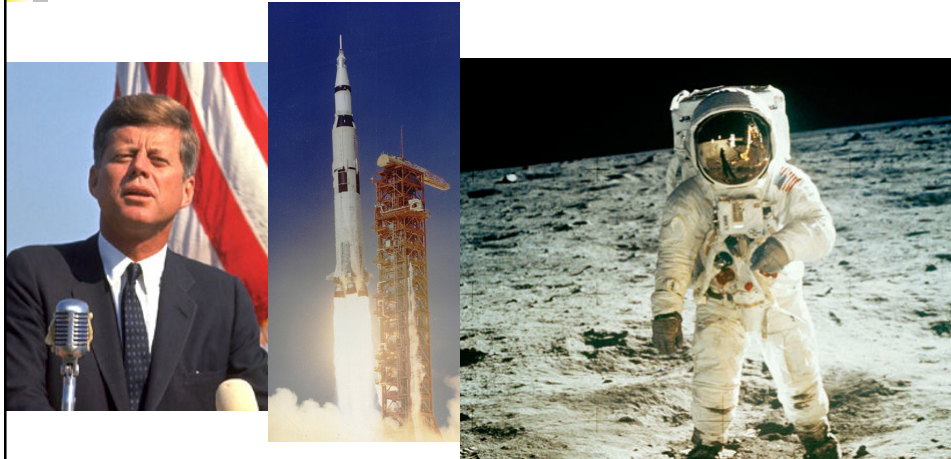
“object of your mission is to explore...the most direct & practicable water communication across the continent, for the purpose of commerce.”

+ geography, geology, astronomy, biology, meteorology

+ Indian languages, laws, customs, religion, agriculture, hunting & fishing



# Kennedy Moon Shot Speech (1961)



“The growth of our science & education will be enriched by new knowledge of our universe & environment, by new techniques of learning & mapping, ... by new tools & computers for industry, medicine, home & school.”



# UN Millennium Development Goals



**WE CAN END POVERTY 2015**  
MILLENNIUM DEVELOPMENT GOALS

A Gateway to the UN System's Work on the MDGs

Background	Reports	Statistics	Calendar	Statements	Media Room	Youth	Get Involved
------------	---------	------------	----------	------------	------------	-------	--------------

Home

UN media contacts

UN Partners on MDGs

**UNDP**  
United Nations Development Programme

**Millennium Campaign**

**UNDESA**  
UN Department of Economic & Social Affairs

**World Bank**

**UNICEF**  
UN Children's Fund

**UNEP**  
UN Environment Programme

**UNFPA**  
UN Population Fund

**WHO**  
World Health Organization

**IMF**  
International Monetary Fund

**UN-HABITAT**  
UN Human Settlements Programme

**FAO**

**What's Going On?**

**Every Woman Every Child. One year progress update**  
A one-year progress update "Saving the Lives of 16 Million", launched on 20 September 2011 at the UN, showed that in the first year of the effort, commitments have been implemented and enhanced, new partners have come on board and funding has been increased. While lauding this progress, Secretary-General Ban Ki-moon noted that millions of women and children are still dying and called for advancing the goal of saving 16 million lives by 2015.

**Governments Line up at UN in Support of International Push on Maternal, Child Malnutrition**

One year after the launch of the **Scale Up Nutrition (SUN)** Movement, a global initiative that aims to improve maternal and child nutrition, representatives of governments, civil society and the private sector joined United Nations agencies to emphasize the importance of good nutrition, especially for mothers and infants during the 1,000 days between pregnancy and age 2. "The lives of millions of children are at stake. We can help them realize their physical and intellectual potential" Mr Ban told the meeting

**MILLENNIUM DEVELOPMENT GOALS**

-  End Poverty and Hunger
-  Universal Education
-  Gender Equality
-  Child Health
-  Maternal Health
-  Combat HIV/AIDS
-  Environmental Sustainability
-  Global Partnership



## Vannevar Bush: FDR's Science Advisor

### *Science: The Endless Frontier* (1945)

- Separates basic (or pure) from applied research
- Urges strong gov't support for academic basic research
- Warns: "applied research invariably drives out pure"

These biased views are still widely held, so a fresh analysis is needed to repair the damage and to provide a guiding framework for scientific researchers across many disciplines.



## What is Scientific Research

- Basic research
  - 
  - 
  -
- Applied research
  - 
  - 
  -



## What is Scientific Research

- Basic research
  - Not motivated by existing needs
  - Understanding nature, developing algorithms
  - Produces general theories
- Applied research
  - 
  - 
  -

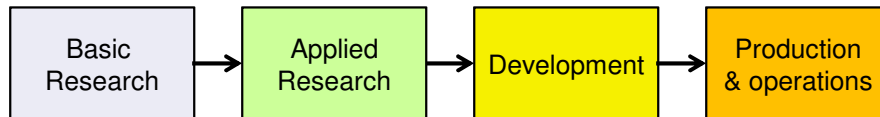


## What is Scientific Research

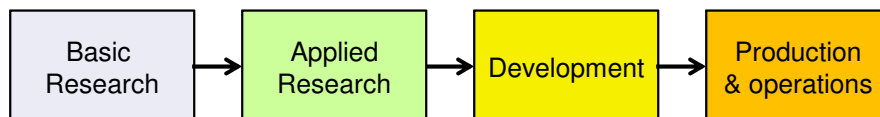
- Basic research
  - Not motivated by existing needs
  - Understanding nature, developing algorithms
  - Produces general theories
- Applied research
  - Anticipates usage by others
  - Suggests social/economic benefits
  - Produces practical results



## Linear Model



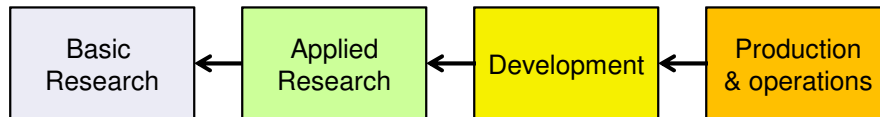
## Linear Model



**Rarely works:**  
**Basic Researchers choose wrong problems →**  
**Technology Transfer is a struggle**



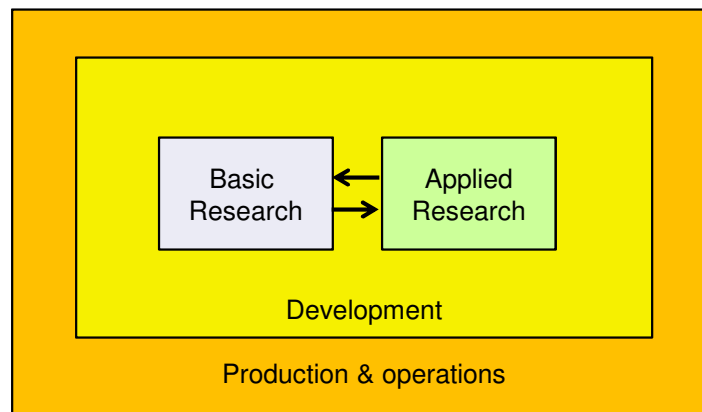
## Reverse Linear Model



**Successful pattern:**  
Listen to industry problems & solve them →  
Technology Transfer is easy



## Ecological Model



<http://www.theatlantic.com/technology/archive/2013/04/toward-an-ecological-model-of-research-and-development/275187/>





## High Impact Research

Address National & International priorities

- 1) Basic & applied questions  
Theoretical & practical outcomes  
Curiosity-driven & mission-driven
- 2) Multiple methods/disciplines
- 3) Interventions in working large-scale systems  
Repeated case studies support or falsify hypotheses

(R.W. Emerson, J. Dewey, W. James, H. Simon,  
A. Spector, W. Hall, T. Berners-Lee,...many of you!)



## Early Work on Software Psychology



- Programming
  - Comprehension
  - Modification
  - Debugging
  - Language design
  - Modularity
- Flowchart usage
- Team work
- Response time

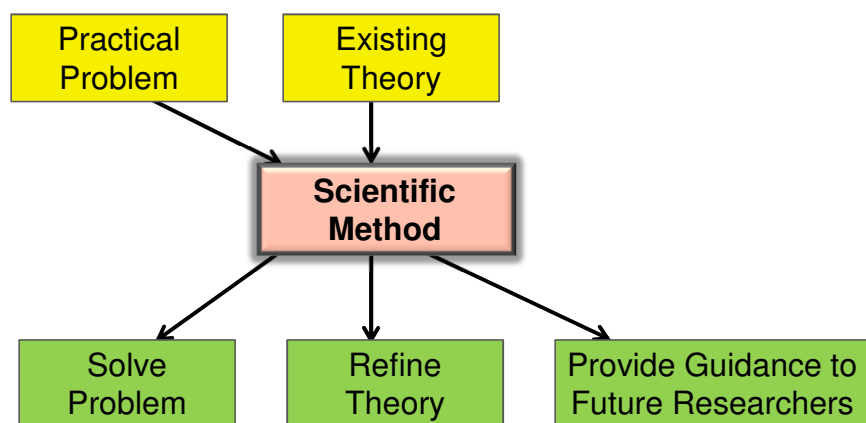


## Scientific Method: Controlled Experiment

- Practical Problem & Existing Theory
- Write a Lucid & testable Hypothesis
- Alter a small number of independent variables (treatment)
- Select & assign subjects
- Control other variables
- Measure small number dependent variables
- Apply statistical test
- Solve problem, refine theory, produce guidance for future researchers



## Scientific Method: 2 parents, 3 children



## What kinds of theories are there?

- Descriptive
- Explanatory
- Predictive
- Prescriptive
- Generative



## What kinds of theories are there?

- Descriptive
- Explanatory
- Predictive
- Prescriptive
- Generative
- Cognitive
- Perceptual
- Motor skills
- Small Group Teamwork
- Organizational/Leadership
- Social/Cultural



# Software Engineering Validation Methods

- **Observational**
  - Project monitoring
  - Case study
  - Assertion
  - Field study
- **Historical**
  - Literature search
  - Legacy data
  - Lessons learned
  - Static analysis
- **Controlled**
  - Replicated
  - Synthetic
  - Dynamic analysis
  - Simulation

(Zelkowitz, *IEEE Computer* 1998)



# Software Engineering Validation Methods

- **Observational**

• Project monitoring	1	NO EXPERIMENTATION	167
• Case study	58		
• Assertion	192		
• Field study	7		
- **Historical**

• Literature search	17		
• Legacy data	11		
• Lessons learned	49		
• Static analysis	4		
- **Controlled**

• Replicated	6		
• Synthetic	12		
• Dynamic analysis	7		
• Simulation	31		

(Zelkowitz, *IEEE Computer* 1998)



# Software Engineering Validation Methods

- **Observational**
    - Project monitoring 1
    - Case study 58
    - Assertion 192
    - Field study 7
  - **Historical**
    - Literature search 17
    - Legacy data 11
    - Lessons learned 49
    - Static analysis 4
  - **Controlled**
    - Replicated 6
    - Synthetic 12
    - Dynamic analysis 7
    - Simulation 31
- NO EXPERIMENTATION 167
- Authors need to:
    - state their goals clearly
    - state how they validate hypotheses
    - use terms correctly
      - “case study”
      - “controlled experiment”
      - “lessons learned”

(Zelkowitz, *IEEE Computer* 1998)



# Evaluation Methods

## Ethnographic Observational Situated

- Multi-Dimensional
- In-depth
- Long-term
- Case studies



## Evaluation Methods

### Ethnographic Observational Situated

- Multi-Dimensional
- In-depth
- Long-term
- Case studies

Domain Experts  
Doing Their Own Work  
for Weeks & Months



## Evaluation Methods

### Ethnographic Observational Situated

- Multi-Dimensional
- In-depth
- Long-term
- Case studies

# MILCs

Shneiderman & Plaisant, *BeLIV workshop*, 2006



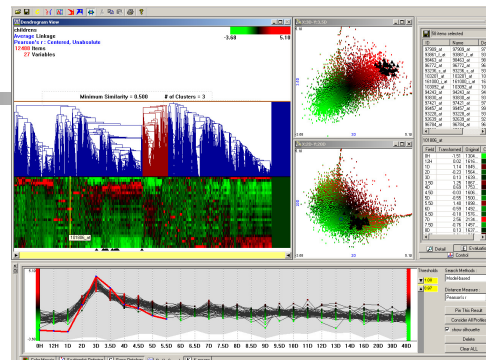
## Case Study Methodology

- 1) Interview (1 hr)
- 2) Training (2 hr)
- 3) Early Use (2-4 weeks)
- 4) Mature Use (2-4 weeks)
- 5) Outcome (1 hr)



## MILC example

- Evaluate Hierarchical Clustering Explorer



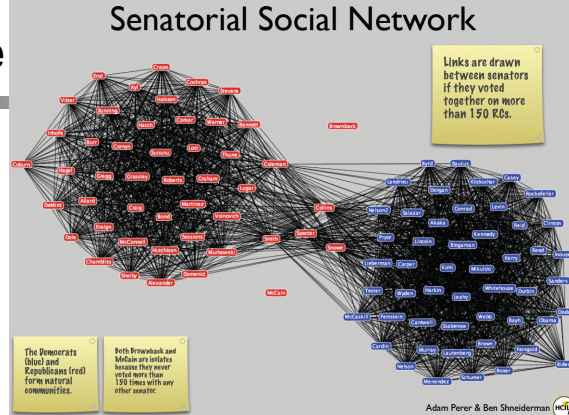
- Focused on rank-by-feature framework
- 3 case studies, 4-8 weeks (molecular biologist, statistician, meteorologist)
- 57 email surveys
- Identified problems early, gave strong positive feedback about benefits of rank-by-feature

Seo & Shneiderman, *IEEE TVCG* 12,3, 2006



## MILC example

- Evaluate Social Action



- Focused on integrating statistics & visualization
- 4 case studies, 4-8 weeks  
(journalist, bibliometrician, terrorist analyst, organizational analyst)
- Identified desired features, gave strong positive feedback about benefits of integration

Perer & Shneiderman, CHI2008




## Science 1.0

- Reductionist
- Controlled Experiments
- Laboratory
- Natural World






<b>Science 1.0</b>	<b>+</b>	<b>Science 2.0</b>
• Reductionist	→	Contextual
• Controlled Experiments	→	Interventions & Case Studies
• Laboratory	→	Situated
• Natural World	→	Made World



<b>Science 1.0</b>	<b>+</b>	<b>Science 2.0</b>
• Reductionist	→	Contextual
• Controlled Experiments	→	Interventions & Case Studies
• Laboratory	→	Situated
• Natural World	→	Made World
• Hypothesis Testing	→	Hypothesis Testing
• Predictive Theories	→	Predictive Theories
• Replications	→	Replications

*Science* 319 (March 7, 2008), 1349-1350.  
<http://www.sciencemag.org/cgi/content/full/319/5868/1349>



# High Impact Research

Address National & International priorities

- 1) Basic & applied questions  
Theoretical & practical outcomes  
Curiosity-driven & mission-driven
- 2) Multiple methods/disciplines
- 3) Interventions in working large-scale systems  
Repeated case studies support or falsify hypotheses

(R.W. Emerson, J. Dewey, W. James, H. Simon,  
A. Spector, W. Hall, T. Berners-Lee,...many of you!)



The screenshot shows the HCIL website homepage. At the top left is the HCIL logo and the text "Human-Computer Interaction Lab University of Maryland". To the right is a search bar labeled "search hcil". Below this is a navigation menu with links for "News + Events", "About HCIL", "People", "Research", "Publications", "Academics", and "Sponsorship". On the left side, there are statistics: "quick find :: Current Research Projects", "30+ years of Tech Reports Online", and "20+ years of Video Reports Online". Below these is a "NEWS" section. The main content area features a large group photo of the lab members waving. Below the photo, the text reads "31st Annual Symposium May 29, 2013". At the bottom, the website URL "www.cs.umd.edu/hcil" and the Twitter handle "@benbendc" are displayed. The HCIL logo is also present in the bottom right corner of the page.