WOX7001
Research Methodology
Lecture 1: Introduction

Group 1 + Remote Learning (RL) MDS	Wednesday 6.00 – 9.00 PM
Group 2 MDS, MCyberSec, MAI	Saturday 8.30 – 11.30 AM

Course Learning Outcomes

Learning Outcomes	Week	Assessment Method
1. Describe appropriate methodologies used in computer science and information technology research. (C6)	11	Quiz (25%)
2. Devise a plan to be carried out within a feasible duration for answering research problems and questions identified. (P3)	8	Individual Assignment (25%)
3. Demonstrate attitude and character in line with professional and ethical codes in computer science and information technology research. (A3)	12-14	Online Presentation (10%) Research Proposal (40%)

Week / Date	Topic	Week	
1	Introduction to academic research	8	Qualitative research
2	Research problem, research objectives, research questions, scope and contributions	9	Ethical issues: Plagiarism, similarity and UM IPS guidelines
3	Research types (quantitative, qualitative, mixed method, etc)	10	Research Proposal: Writing up
4	Literature review	11	**Quiz (25%)**
5	Systematic Review	12	**Submission of Research proposal (30%) + Online Presentation (10%)**
6	Research methodology in computer science Experimental, simulation, theoretical, case study	13	**Submission of Research proposal (30%) + Online Presentation (10%)**
7	Quantitative research	14	**Submission of Research proposal (30%) + Online Presentation (10%)**

Continuous Assessment (100%)

Individual Assignment (25%)

Online Quiz (25%)

- Research Proposal (40%)
- Presentation of Research Proposal (10%)

Assignments

- Individual Assignment 1:
  - Find at least 10 journal articles (related to your research field) and write a constructive review, comparison table and taxonomy.
- Individual Assignment 2:
  - Write a research proposal report
  - Present your research proposal (synchronous)

Lecturer Details

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Why do research?

- ✓ Desire to get research degree???
- ✓ Personal curiosity, desire to express and engage
- ✓ To learn and be the expert

- ✓ Enjoyment – new people and new places

What is Research

- **Meaning:**
- Re: once more, afresh, anew
- Search: look thoroughly over something
- Research: the systematic **investigation** into a topic and study of materials and sources in order to establish facts and reach new conclusions

What is Research

"Research is the systematic approach to obtaining and confirming new and reliable knowledge"

- Systematic and orderly (following a series of steps)
- Purpose is new knowledge, which must be reliable

This is a general definition which applies to all disciplines

Research IS NOT

Accidental discovery :

1. Accidental discovery may occur in structured research process
2. Usually takes the form of a phenomenon not previously noticed
3. May lead to a structured research process to verify or understand the observation

Research IS NOT

Data Collection

- an intermediate step to gain reliable knowledge
- collecting reliable data is part of the research process

Research IS NOT

Searching out published research results in libraries (or the internet)

- This is an important early step of research
- The research process always includes synthesis and analysis
- But, just reviewing of literature is not research

Research IS…

1. Searching for explanation of events, phenomena, relationships and causes
   - What, how and why things occur
   - Are there interactions?
2. A process
   - Planned and managed – to make the information generated credible
   - The process is creative
   - It is **circular** – always leads to more questions

Research IS…

- All well designed and conducted research has potential application.
- Failure to see applications can be due to:
  - Users not trained or experienced in the specialized methods of economic research and reasoning
  - Researchers often do not provide adequate interpretations and guidance on applications of the research
- Researchers are responsible to help users understand research implications.

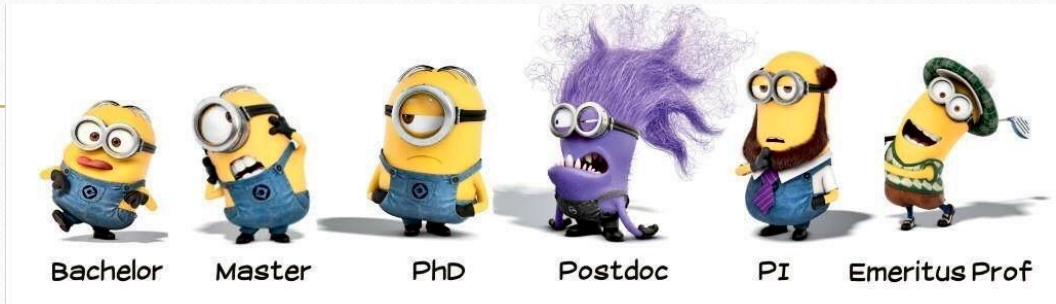
Methodology vs Method

- Difference between research methodology from research methods:
- **Methodology** – the study of the methods involved in some field, endeavor, or in problem solving
  - Example: a collection of theories, concepts or ideas; a comparative study of different approaches
- **Methods** – specific details and/or procedures to accomplish a task to reach a certain objective
  - Example: regression analysis, optimization models, surveys, econometrics

Thesis / Dissertation

- A **thesis** statement declares what you believe and what you intend to prove.
  - PhD Thesis / Master Degree Dissertation
- 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.

Comparison between Masters and PhD. Research



- **Masters**
  - To solve a problem using the methodology that you have learned
- **PhD**
  - Using the methodology that you have learned and experience of solving problem to produce something new

Thesis Structure

ABSTRACT the essential message

1) Summary of your basic message

INTRODUCTION setting the scene

2) Your statement of **topic** and **focus**
3) Your vision and motivation for the research, and how you locate it within broader work
4) Your choice of research **setting** and overall data collection **strategy**
5) How your **thesis** is structured

LITERATURE REVIEW

RESEARCH METHODOLOGY

6) Your **conceptual framework**

7) What **you have learnt** from previous research and **how you position yourself** in relation to current discussions, within which (a) your **topic** and (b) your **methodology** are located

8) Evidence that you are **well informed**

DESCRIPTION OF RESEARCH PROCEDURES

9) How you chose your **core setting** and relevant **data sources**
10) What we need to know about the setting
11) How you developed an appropriate research **strategy**
12) How you gained **access** and collected **data**
13) A catalogue of **research activities** and data **collected**
14) How you structured your analysis and arrived at your choice of **themes** and **headings**
15) Your system for **presenting data** (e.g. coding, anonymising)

DISCUSSION OF DATA

16) Structured **using the themes and headings** described above

17) What **you have learnt** from the data

18) How the data provides **evidence for what you have found**

IMPLICATIONS

19) A **summary** of what you have found during your research

20) What you think it all **means**

CONCLUSION - summing up and recommendations

21) Your final comments on all the basic points in your argument

Written study, structure and functions (Holliday 2007: 43)

Classification of Research

- Before classification, we must first **define** types of research
- Different criteria are used to classify research types

Basic vs Applied Research

- Basic – to determine or establish fundamental facts and relationships within a discipline or field of study. Develop theories … (examples in economics?)
- Applied – undertaken specifically for the purpose of obtaining information to help resolve a particular problem
- The distinction between them is in the application
  - Basic has little application to real world policy and management but could be done to guide applied research

Disciplinary, Subject-matter, and Problem-solving Research (Johnson, 1986)

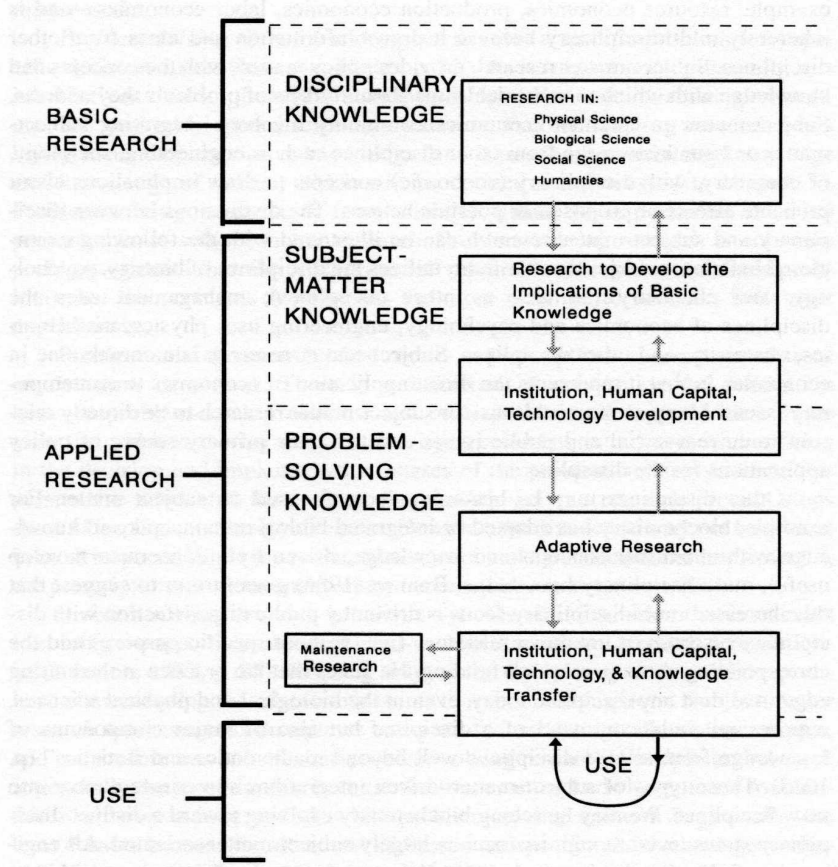


Figure 2.1. Relationship among research, knowledge, and use (Bonnen, 1986).

Disciplinary

- designed to improve a discipline
- dwells on theories, fundamental relationships and analytical procedures and techniques
- In economics, the intended users are other economists
- Provides the conceptual and analytical base for other economic researches
- It is synergistic and complementary with subject matter and problem-solving research

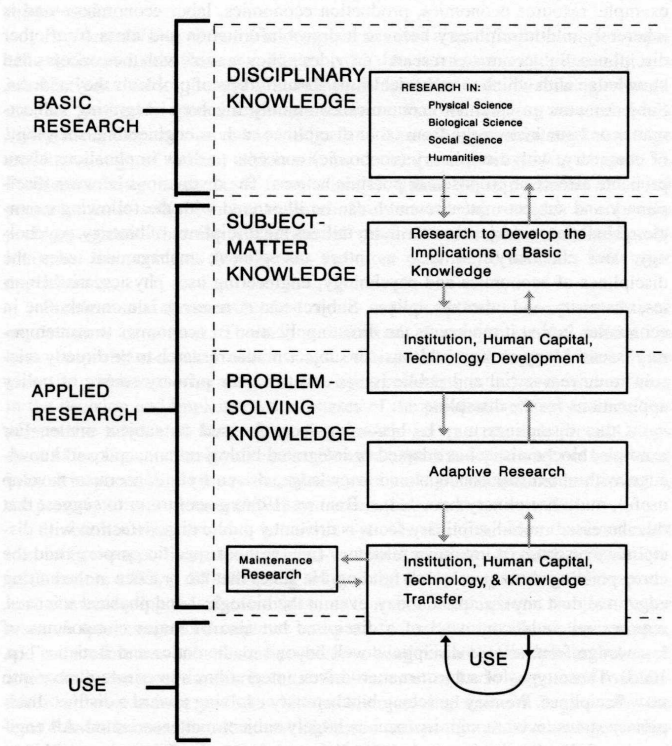
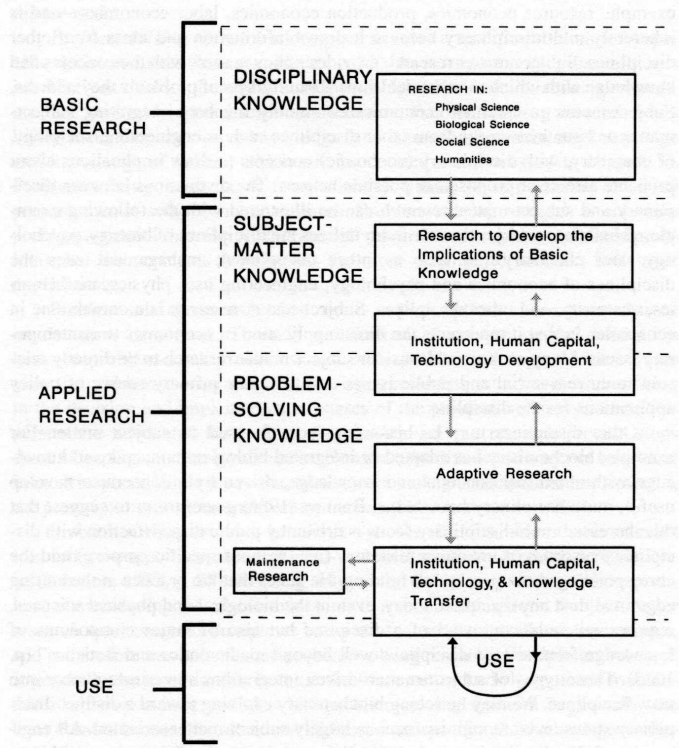


Figure 2.1. Relationship among research, knowledge, and use (Bonnen, 1986).

Disciplinary

- Provides the foundations for applied research
- Circular as applied research reveals the shortcomings of disciplinary research
- Examples of some economic theories?

  (supply & demand, price elasticity, consumer utility …)



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Subject-matter research

"research on a subject of interest to a set of decision makers "

Tends to follow subject-matter boundaries within a discipline (eg. resource economics, production economics, labor economics)

Inherently multidisciplinary, drawing information from many disciplines

- eg. consumer economic draws from psychology, natural resource economics from biology, economic policy from political science

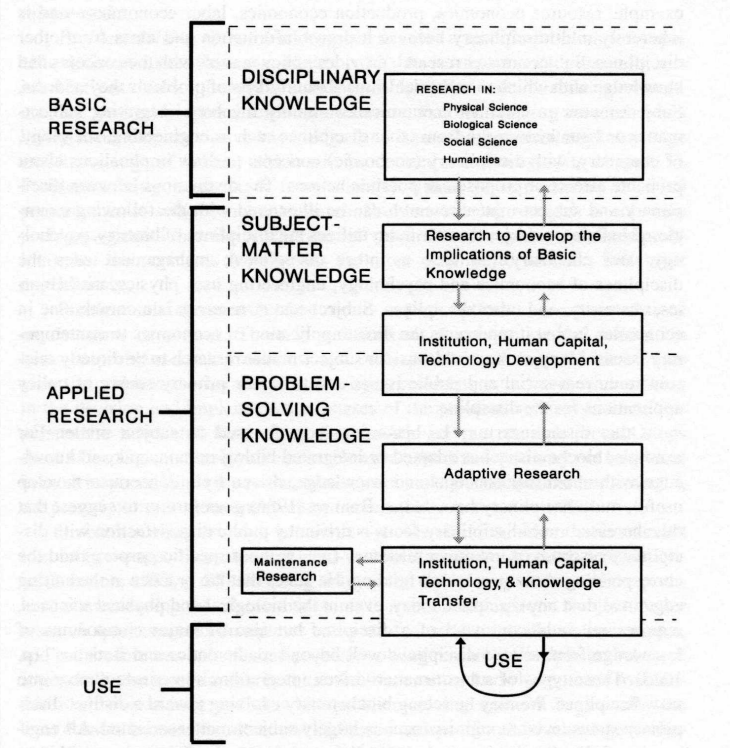
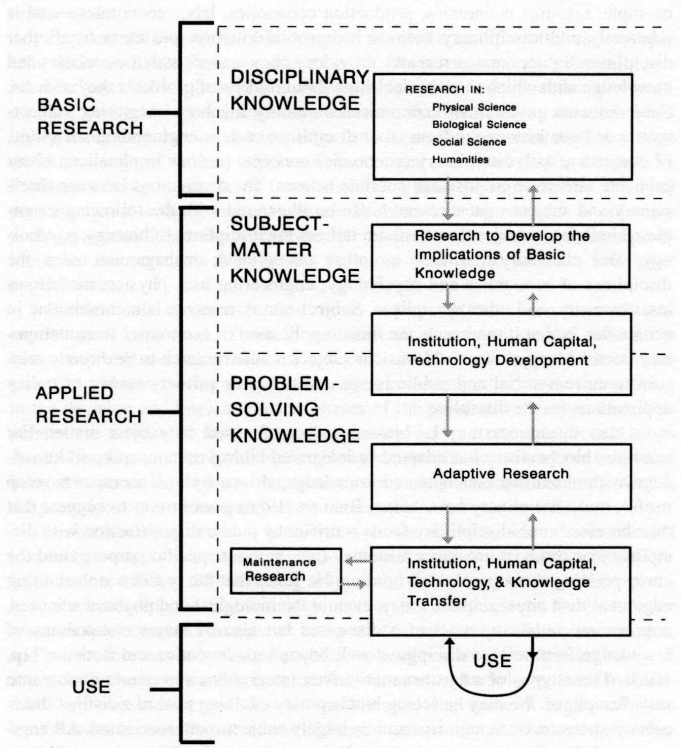


Figure 2.1. Relationship among research, knowledge, and use (Bonnen, 1986).

Subject-matter research

- Provides policy makers with general knowledge to make decisions about various problems.
- A primary source of policy applications for economics
- Subject-matter research is a cornerstone in economics – it involves direct application of economics to contemporary issues.



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Problem-solving research

- Designed to solve a specific problem for a specific decision maker often results in recommendations on decisions or actions.
- Problem-solving research is holistic – uses all information relevant to the specific problem (while disciplinary research tends to be reductionist).
- Disciplinary research is generally the most "durable" (long lasting); problem-solving research the least durable.

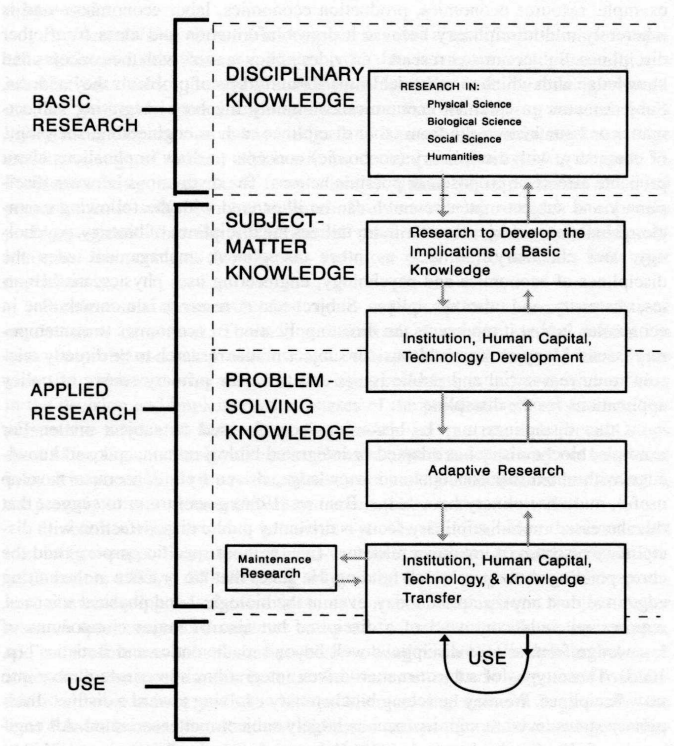


Figure 2.1. Relationship among research, knowledge, and use (Bonnen, 1986).

Descriptive vs Analytic

- Descriptive Research – the attempt to determine, describe, or identify something
  - The intent is often synthesis, which pulls knowledge or information together
- Analytic – the attempt to establish why something occurs or how it came to be
- All disciplines generally engage in both

Research Process

- The process is initiated with a question or problem (**step 1**)
- Next, goals and objectives are formulated to deal with the question or problem (**step 2**)
- Then the research design is developed to achieve the objectives (**step 3**)
- Results are generated by conducting the research (**step 4**)
- Interpretation and analysis of results follow (**step 5**)

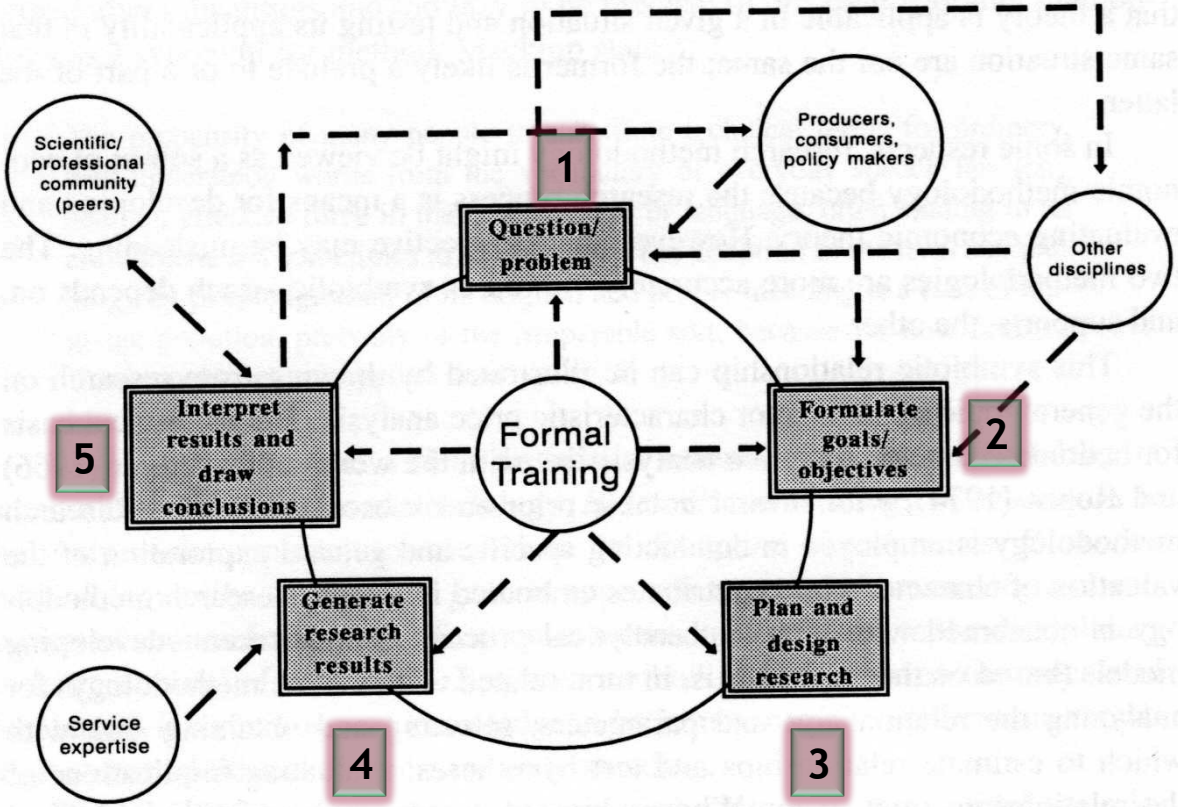


Figure 2.2. Schematic of research process.

Creativity in the Research Process

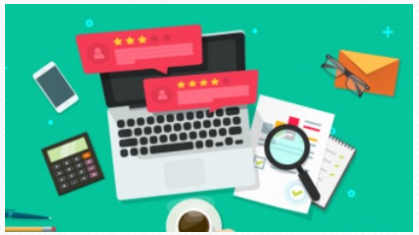
- Research is a creative process
- *"…research includes far more than mere logic … It includes insight, genius, grouping, pondering - 'sense' … The logic we can teach; the art we cannot"*
- Research requires (or at least works best) with imagination, initiative, intuition, and curiosity.
- There are different types of creativity, characteristic of different situations – "applied" and "theoretical" most closely associate with economic research

Research Approaches

- Plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation.
- Informing the decision should be the philosophical assumptions the researcher brings to the study; procedures of inquiry (called research designs); and specific research methods of data collection, analysis, and interpretation.
- The selection of a research approach is also based on the nature of the research problem or issue being addressed, the researchers' personal experiences, and the audiences for the study.

What types of research approach?

- (a) qualitative, (b) quantitative, and (c) mixed methods.
- Often the distinction between **qualitative research** and **quantitative research** is framed in terms of using words (qualitative) rather than numbers (quantitative), or using closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions).



Quantitative

- ✓ **Measure prevalence** of issues, **verify hypotheses** and **establish causal relations** between variables
- ✓ **Large samples, structured** data collection, and predominantly **deductive** analysis

Qualitative

- ✓ **Explore and discover themes, develop theories,** rather than verify hypotheses and measure occurrences
- ✓ **Smaller samples, semi-structured** data collection, **inductive** analysis

Mixed Methods

- ✓ **Combines both qualitative and quantitative** to (1) collect and analyse both types of data and (2) use both approaches in tandem

Qualitative Research

- Qualitative research is an approach for exploring and understanding the meaning individuals or groups ascribe to a social or human problem.
- The process of research involves emerging questions and procedures, data typically collected in the participant's setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data.
- The final written report has a flexible structure.
- Those who engage in this form of inquiry support a way of looking at research that honors an inductive style, a focus on individual meaning, and the importance of rendering the complexity of a situation.

Quantitative Research

- Quantitative research is an approach for testing objective theories by examining the relationship among variables.
- These variables, in turn, can be measured, typically on instruments, so that numbered data can be analyzed using statistical procedures.
- The final written report has a set structure consisting of introduction, literature and theory, methods, results, and discussion.
- Like qualitative researchers, those who engage in this form of inquiry have assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings.

Strength and weakness of quantitative and qualitative methods

	Quantitative	Qualitative
Strength and weakness	Generalization	
	Large sample	Small sample
		details, in depth

Comparing Qualitative and Quantitative Research

Qualitative Research	RESEARCH ASPECT	Quantitative Research
Discover Ideas, with General Research Objects	COMMON PURPOSE	Test Hypotheses or Specific Research Questions
Observe and Interpret	APPROACH	Measure and Test
Unstructured. Free Form	DATA COLLECTION APPROACH	Structured Response Categories Provided
Research is intimately involved. Results are subjective	RESEARCHER INDEPENDENCE	Researcher uninvolved Observer. Results are Objective
Small samples –Often in Natural setting	SAMPLES	Large samples to Produce Generalizable Results [Results that Apply to Other Situations]

Mixed Methods

- Mixed methods research is an approach to inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks.
- The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone.

Characteristics of mixed methods research

- Collect and analyze both quantitative and qualitative data.
- Mix two forms of data in different ways.
- Give priority to one or both forms of data.
- Can be in a single study or in multiple phases of a study.

Why use mixed methods

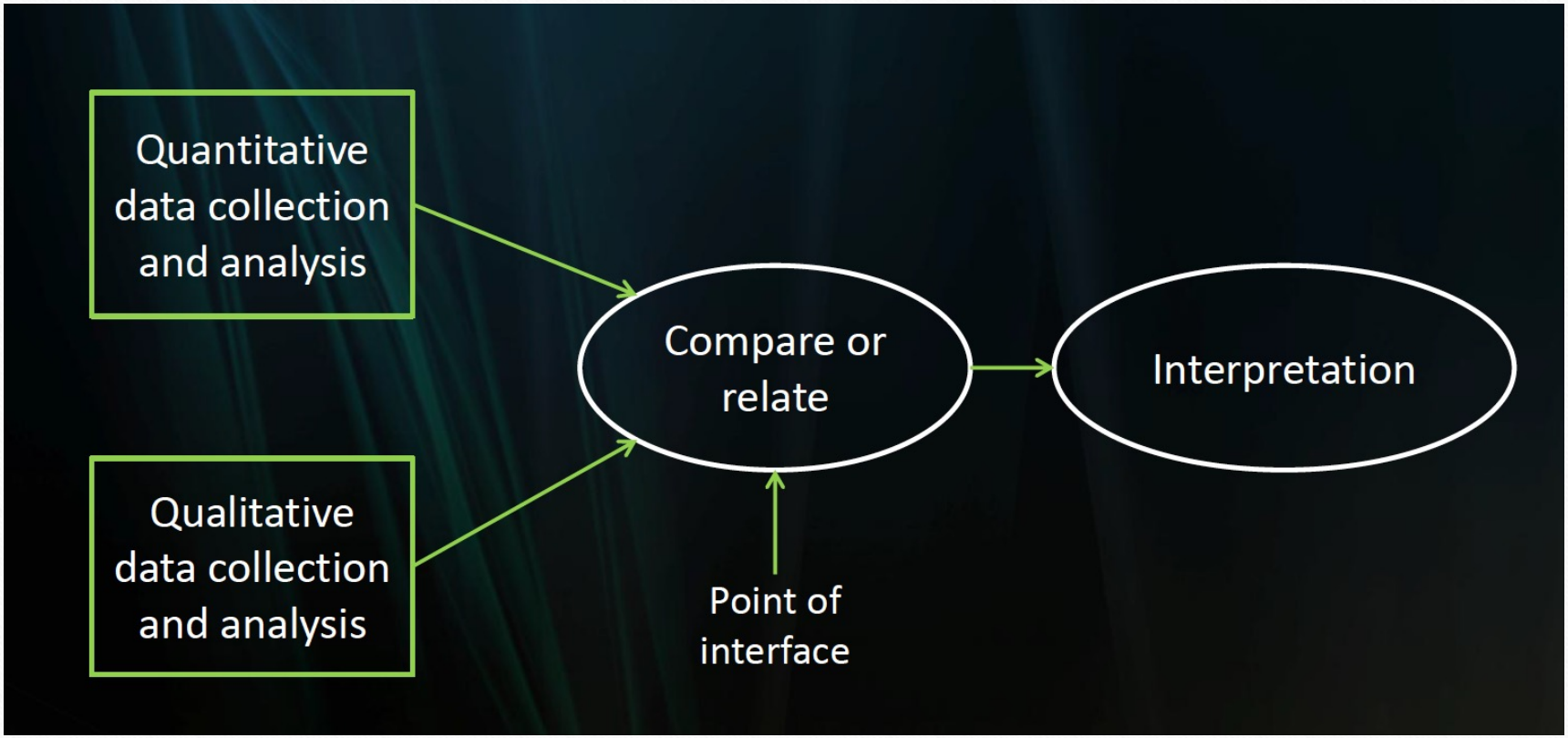
- One data resource may not be enough;
- Initial results need to be further explained;
- A second method is needed to enhance a primary method;
- The project has multi-phases

Point of interface

- is a point where the two strands are mixed: possible point of interfaces
- **Data collection:** quan or qual results build to the subsequent collection of qual or quan data.
- **Data analysis:** transform one type of data into other type of data and analyze combined data.
- **Interpretation:** comparing or combining results from both methods

Mixed Methods: Examples

- Similar results from different perspectives: collect data on quantitative instrument and on qualitative data based on focus groups.
- Collect quantitative data first and follow up with interviews to help explain their outcomes from quantitative data.
- Use interviews to explores how individuals describe a topic and use the findings to develop quantitative data collection instrument.


Quantitative data collection and analysis
Qualitative data collection and analysis
Compare or relate
Point of interface
Interpretation

Deductive (quantitative) vs. inductive (qualitative) analysis approach

Deductive Analysis (Theory = starting point)	Inductive Analysis (Theory = end point)
Define hypothesis and identify the key variables within it	Use semi-structured methods to explore and gather information
Frame research question based on key variables within the hypothesis statement	Analyse data to identify, form themes and categories
Measure or observe key variables using statistical analysis methods	Look for broad patterns, generalisations or theories from themes and categories
Hypothesis tested and verified/ not verified	**A theory or hypothesis developed based on patterns, generalisations and theories identified**

To be Cont'd

Basic steps in CS Research

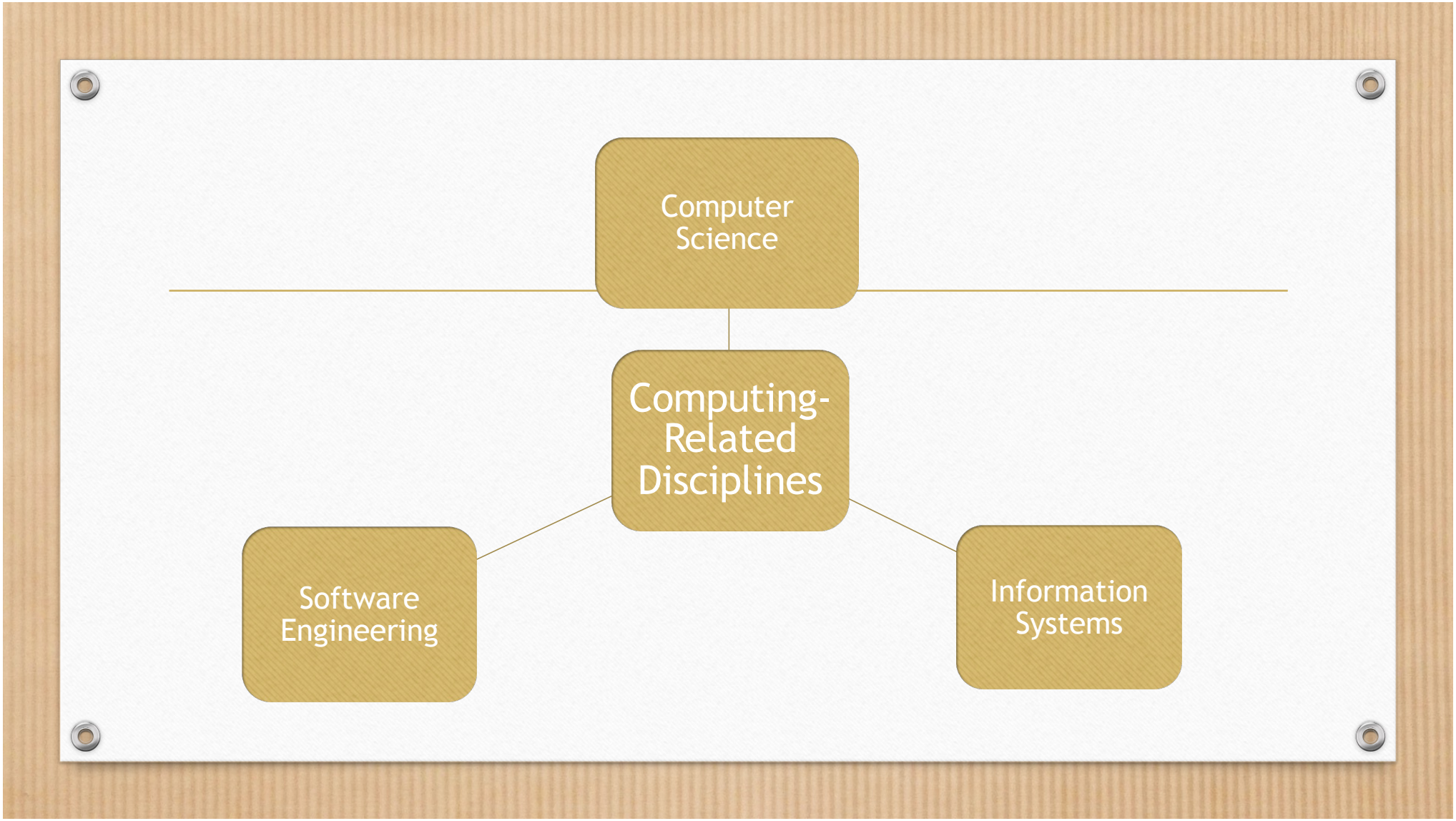
- The techniques applied in CS research include formal logic, automata theory and the theory of computational complexity.
  - The tools for expressing this ideas include formal languages such as The Unified Modelling Language (UML), *Petri nets, Z and Finite State Automata (FSA)*.
- Computer programming languages such as Java, C, C++ and Fortran and simulation software such as MatLab and Mathematical are common implementation tools.

Scope of Computer Science

- **Traditional research in Computer Science**
  - Oriented towards scientific and engineering models of research
- **Current scenario**
  - Scope of computer science has since been expanding
  - Many research topics currently considered part of the discipline in Computer Science are technology driven rather than theory driven.
    - Topics that are technology driven are difficult to assess using pure scientific criteria.

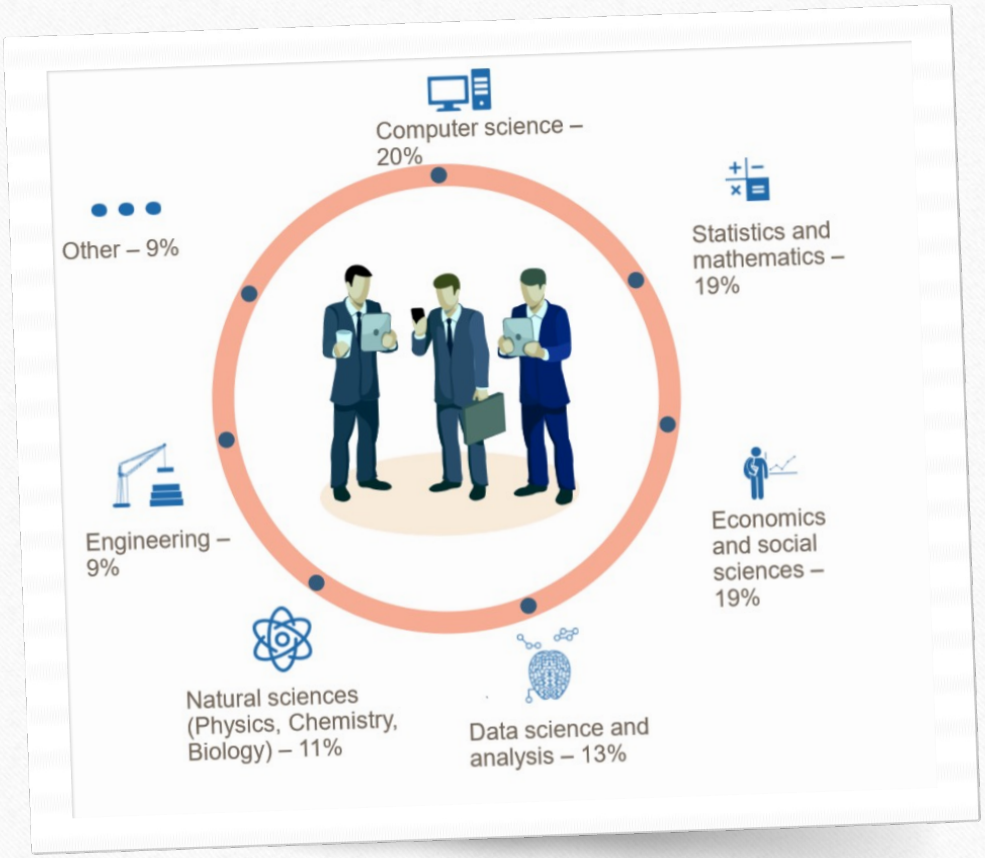
Level of Study in CS Research

- An abstract concept (AC) such as a data model
- A computing element (CE) such as an algorithm
- A system, a project, or an organization.
- Finally, the origin of the study's theoretical base.


Computer Science
Computing-Related Disciplines
Software Engineering
Information Systems

Major Categories

- ✓ Problem-solving concepts
- ✓ Computer concepts
- ✓ Systems/software concepts
- ✓ Data/information concepts
- ✓ Problem-domain-specific concepts
- ✓ Systems/software management concepts
- ✓ Organizational concepts
- ✓ Societal concepts
- ✓ Disciplinary issues



Categories of Research in Computer Science

- 4 main categories of research in CS [in an article by Chris Johnson]:
  - Study of or exploring on what is possible
    (Category A)
  - Study of real-world phenomena or existing naturally occurring information-processing systems
    (Category B)
  - Research involving creation of new useful automated or information-processing systems (Category C)
  - Research related to creation and evaluation of tools, formalisms and techniques to support the activities of all other categories of research (Category D)

Research in Computer Science

- One category that is not really a sub-discipline of CS, but a multi-disciplinary research area:
  - Research related to social and economic impact issues of development in computing technology (Category E)
- Each of these categories builds on and contributes to the others.

Research into What is Possible (Category A)

- Includes a lot of work using mathematics and logic
- Pure theoretical work providing concepts, models, theorem or techniques relevant to other categories of research.
- Includes work using formal approach and less formal approach
  - Formal, e.g. based on mathematical theory
  - Semi-formal: less rigorous using other modes of theory, e.g.
    - Textually based
    - Graphical notational based

Research into What is Possible (Category A) - Formal

- Formal includes work involving mathematics and logic
  - Based on mathematical theory
- Related to work on, e.g.:
  - Semantics of computation
  - Theorems relating to limits of computation
  - Complexity
  - properties of mechanisms for cryptography

Research into What is Possible (Category A) - Formal

- properties of mechanisms for cryptography
- Study behavioural properties of different types of mechanisms/architectures/systems, e.g. using petri nets, such as:
  - liveness, reachability, boundedness, reversability, coverability, persistence, etc
- mathematical analysis of various forms of computations
- studies of the expressive power of different formalisms
  - Richness in concepts

Research into What is Possible (Category A) - Formal

- Example: Formal Definition of a Petri Net
- Example: A petri net (N, Mo) is said to be lively (i.e. Mo is said to be a live marking for N) if, no matter what marking has been reached from Mo, it is possible to be ultimately fire any transition of the net by progressing through some further firing sequence.

A Petri net is a 5-tuple, $PN = (P, T, F, W, M_0)$ where:

$P = \{p_1, p_2, \cdots, p_m\}$ is a finite set of places,
$T = \{t_1, t_2, \cdots, t_n\}$ is a finite set of transitions,
$F \subseteq (P \times T) \cup (T \times P)$ is a set of arcs (flow relation),
$W: F \to \{1, 2, 3, \cdots\}$ is a weight function,
$M_0: P \to \{0, 1, 2, 3, \cdots\}$ is the initial marking,
$P \cap T = \varnothing$ and $P \cup T \neq \varnothing$.

A Petri net structure $N = (P, T, F, W)$ without any specific initial marking is denoted by N.

A Petri net with the given initial marking is denoted by (N, M_0).

Research into What is Possible (Category A) - Formal

- Other works are on analysis of properties of different types of, e.g.:
  - Information-processing architectures
  - Decision support systems
  - Intelligent caching techniques or systems
  - Network protocols
  - Scheduling algorithms
- Study of types of virtual machines and their properties.

Research into What is Possible (Category A) – Semi-Formal

- Semi-formal or less formal includes works that are less rigorous.
- Work on exploratory investigations of :
  - new types of architectures including virtual machine architectures
  - hardware and software mechanisms
  - forms of network protocols/communication, ontologies, etc in order to investigate their properties and their trade-offs

Research into What is Possible (Category A) – Semi-Formal

- Exploration of various forms of representation or high-level architectures for use in intelligent systems.
- May lead to new formal, mathematical development.
- Builds on and abstracts from experience gained in tasks in other categories.

Study of real-world phenomena or existing naturally occurring information-processing systems (Category B)

- Includes research on real-world phenomena or naturally occurring information-processing systems such as
  - human body and brain
  - insert colonies
  - social and economic systems
  - working of the universe
  - Weather patterns
  - processes of biological evolution
  - other occurrences of events, etc

Study of real-world phenomena or existing naturally occurring information-processing systems (Category B)

- Work involving scientific research:
  - attempt to understand, explain or model, things that exist in the world or other real-world phenomena
- Such understanding can sometimes lead to useful practical applications
  - by enabling us to explain, predict, control and modify some of the behaviour of these systems or natural phenomena after understanding them.

Study of real-world phenomena or existing naturally occurring information-processing systems (Category B)

- Study of different forms of computation allows us to find new ways of formulating and testing powerful models and theories for explaining and predicting natural phenomena.
  - To model and explain aspects of human-intelligence
- Relevant to work on:
  - Analysis and simulation of human engineering activities
  - AI or cognitive science on simulation of human design processes

Study of real-world phenomena or existing naturally occurring information-processing systems (Category B)

- Activity of engineers working individually, or in teams, is an example of a naturally occurring process
  - Therefore, empirical investigations of different kinds of practices, methodologies, languages, tools, etc, and how they work, are under this category of research.

Research on creation of new useful automated or information-processing systems (Category C)

- The goal is to create new practically useful systems that add to the body of knowledge
  - i.e. must increase knowledge, such as
    - Increase our explicit knowledge about how to specify, design, build, test, maintain, improve, or evaluate information-processing systems
- Examples are:
  - The original idea of the www;
  - Design of a secure and robust air traffic control system, based on a large and complex collection of ideas;
  - A novel nationwide IS for health service.

Research on creation of new useful automated or information-processing systems (Category C)

- May need the use of knowledge and techniques from many disciplines.
- Related to engineering applications
  - Research closely related to production, analysis and evaluation of practical applications
- Overlaps with Category B on creation of explanatory theories and models
  - normally involves designing and implementing new and complex systems requiring significant engineering skills

Research on creation of new useful automated or information-processing systems (Category C)

- Provide or create new or improved types of artifacts capable of performing functions previously performed by natural systems such as humans, e.g.
  - Proving mathematical theorems, doing numerical computations
  - Translating from one language to another
  - Design new machines
  - managing medical records
  - Weather forecast, face recognition
  - factory automation, auto-pilot
  - Generate code from requirement specifications.

Research on creation of new useful automated or information-processing systems (Category C)

- Develop systems to perform tasks that could not achieved at all previously, e.g.
  - construction of global communication networks
  - Accurately forecasting the weather
  - Controlling extremely complex machines and factories
  - Nuclear reactor systems for generating electricity
  - Systems aiding in harnessing water, wind and solar energy for electricity

Research on creation and evaluation of tools, formalisms and techniques (Category D)

- Research related to creation and evaluation of tools, formalisms and techniques/methods to support the various activities of research.
  - Work involving processes of performing the activities/tasks in the previous categories.

Research on creation and evaluation of tools, formalisms and techniques (Category D)

- Involves a diverse range of activities, including :
  - Designing new programming languages or new formalisms for expressing requirements
    - e.g. creation of a new modeling tool.
  - Compilers, tools for validating or verifying programs or other specifications
  - Tools for designing new computing hardware or checking hardware designs
    - e.g. VLSI
  - Automatic program synthesizers, code generators from a complex analysis model, creation of analysis and design methods and tools
  - Tools to support exploratory design of software (e.g. most AI development environments), etc

Research on creation and evaluation of tools, formalisms and techniques (Category D)

- This category of research can be a subset of Category C.
  - Research on design, analysis and testing methodologies as well as to support them, included in this category though it may overlap with other categories.
  - Design and production of new general purpose computers, compilers, OSs, high-level languages, graphical and other interactive devices, falls into both categories C and D.

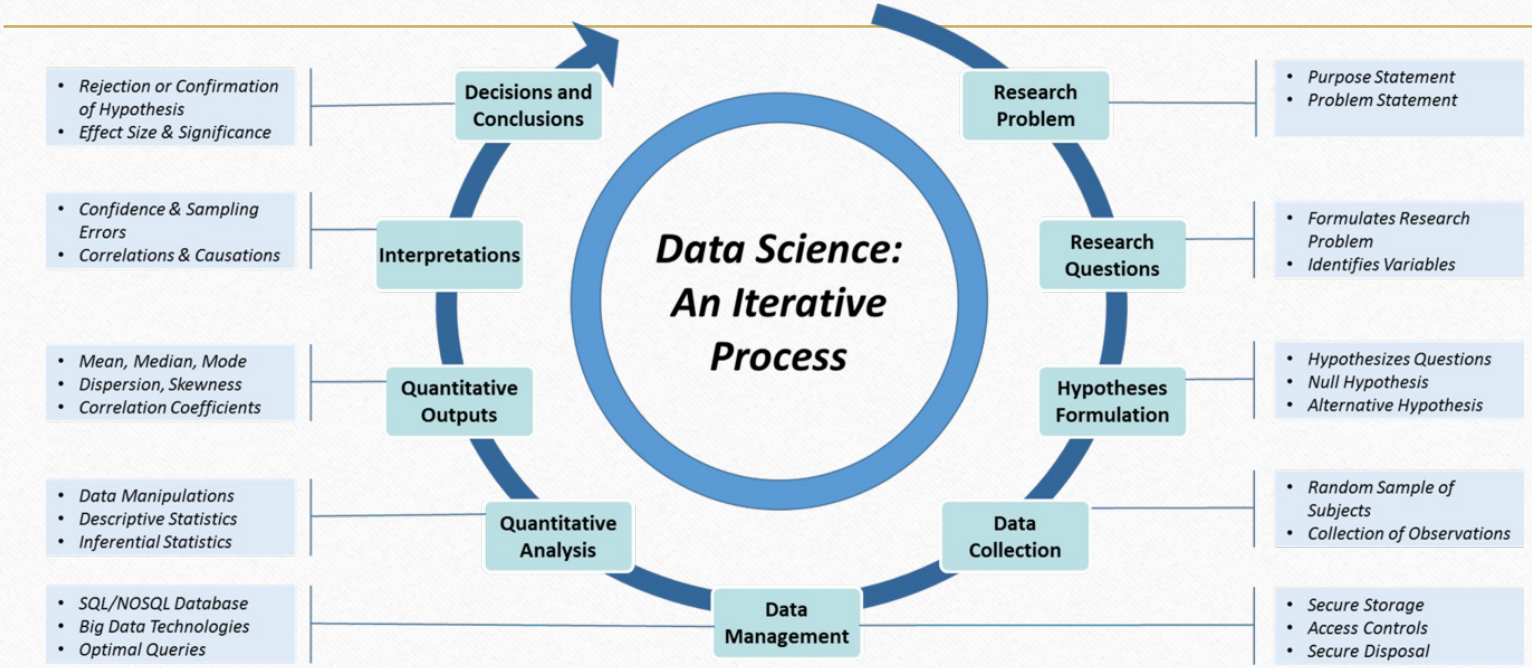
Research related to social and economic issues (Category E)

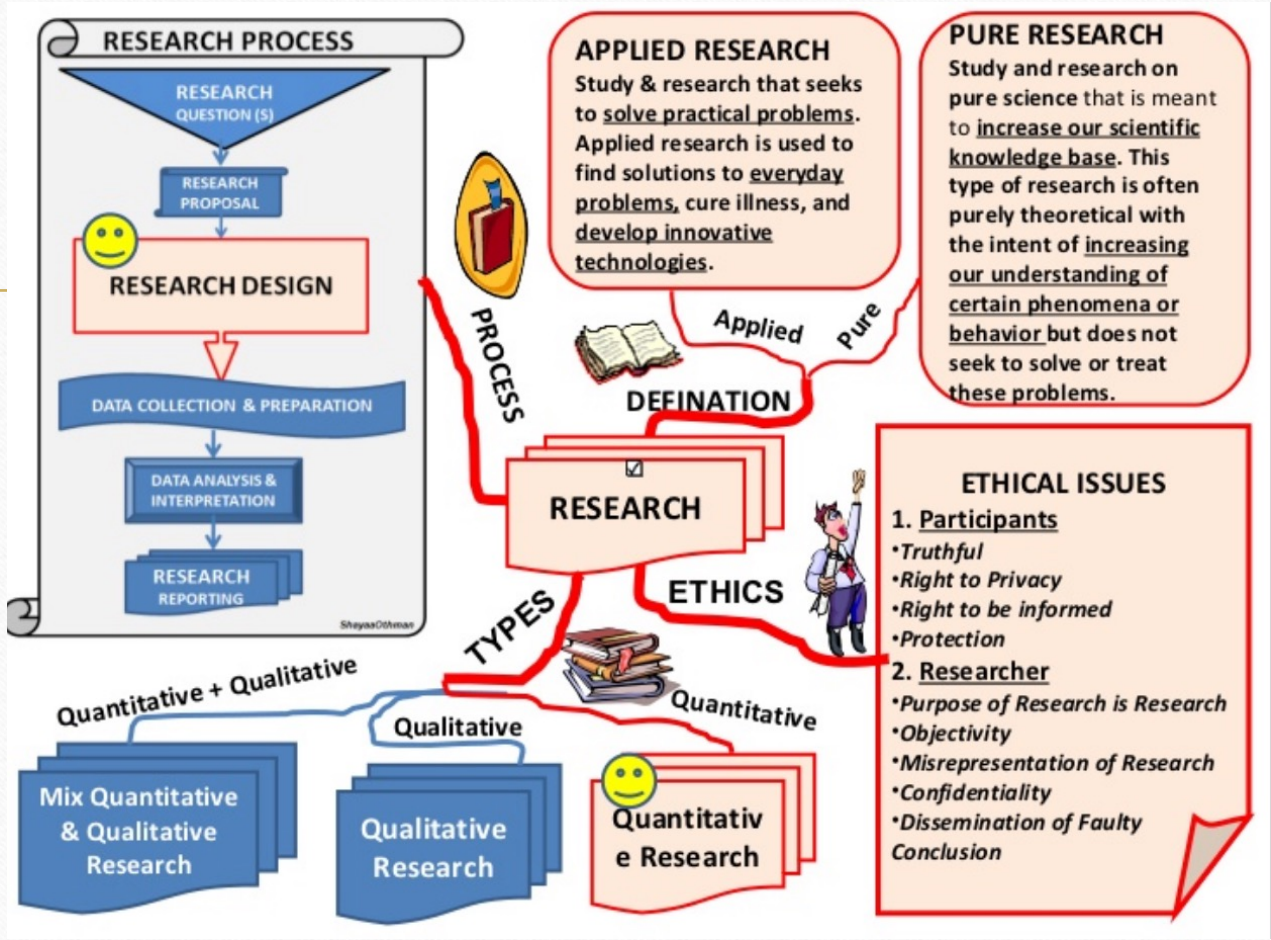
- Not a strictly part of CS
  - Often conducted under disciplines or departments other than CS.
- Research related to the study of
  - social and economic impact of computing
    - ways in which developments in computing technology have influenced social, educational, economic, legal and political processes and structures.
    - ways in which they may influence such processes in the future.
    - changing environments
    - perspectives of humanity: views of human mind from development in AI

Research related to social and economic issues (Category E)

- Analysis of ethical implication of
  - impact of the new technology in jobs, opportunities, power structures, resources, etc for various social groups
- Requires collaboration from other disciplines such as psychology, sociology, economics, management science, political science and philosophy.

Data Science Methodology




RESEARCH PROCESS
RESEARCH QUESTION (S)
RESEARCH PROPOSAL
RESEARCH DESIGN
DATA COLLECTION & PREPARATION
DATA ANALYSIS & INTERPRETATION
RESEARCH REPORTING
PROCESS
APPLIED RESEARCH
Study & research that seeks to solve practical problems. Applied research is used to find solutions to everyday problems, cure illness, and develop innovative technologies.
PURE RESEARCH
Study and research on pure science that is meant to increase our scientific knowledge base. This type of research is often purely theoretical with the intent of increasing our understanding of certain phenomena or behavior but does not seek to solve or treat these problems.
Applied
Pure
DEFINATION
RESEARCH
ETHICS
ETHICAL ISSUES
1. Participants
•Truthful
•Right to Privacy
•Right to be informed
•Protection
2. Researcher
•Purpose of Research is Research
•Objectivity
•Misrepresentation of Research
•Confidentiality
•Dissemination of Faulty Conclusion
TYPES
Quantitative + Qualitative
Qualitative
Quantitative
Mix Quantitative & Qualitative Research
Qualitative Research
Quantitativ e Research

The End