



Research Methodology in CS

Chapter I

204490 Research Methodology in Computer Science



Engineering vs. Science

Traditional View:

Scientists...

- Create knowledge
- Study the World as it is
- Are trained in scientific method
- Use explicit knowledge
- Are thinkers

Engineers...

- Apply that knowledge
- Seek to change the World
- Are trained in engineering design
- Use tacit knowledge
- Are doers

More Realistic View

Scientists...

- Create knowledge
- Are problem---driven
- Seek to understand and explain
- Design experiments to test theories
- Prefer abstract knowledge but rely on tacit knowledge

Engineers...

- Create knowledge
- Are problem---driven
- Seek to understand and explain
- Design devices to test theories
- Prefer contingent knowledge but rely on tacit knowledge

Both involve a mix of design and discovery



Two Types of Research

- Quantitative vs. Qualitative Research
- Quantitative – use of statistical, formulaic or numerical analysis to generate results
 - Main approach: analysis; causal determination, prediction, generalization of findings
 - Results: “This solution is N% better”
- Qualitative – not quantitative; use of non-numeric techniques
 - Main approach: discovery; illumination, understanding, extrapolation to similar circumstances
 - Results: “This is a new way of solving our problem”



Scope of Research

- Varies by level of work
 - Ph.D. students – contribution expected at world level; e.g.
 - background investigation on all past work
 - make meaningful addition to world knowledge
 - Undergraduate students – contribution can be at local to national to world level; e.g.
 - background investigation at university up to world level
 - make meaningful addition to university up to world level of knowledge

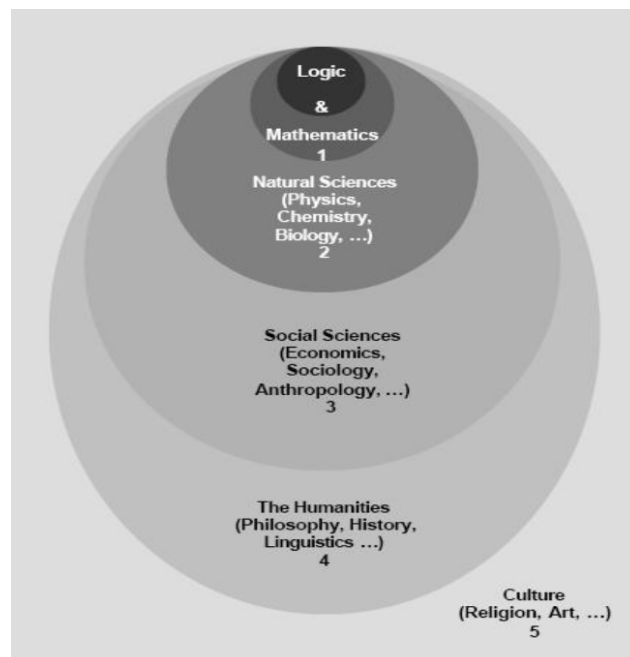


Not CS Research

- Playing with technology
- Book report
- Programming project
- Doing what others have already done
- However, each of these can be done as part of research



Domain Related CS Research

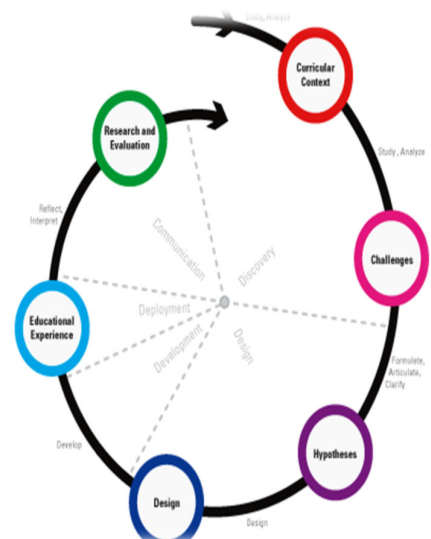


Research Methods in CS

- **Experimental Method**
 - Experimental shows the experiments that will occur in order extract results from real world implementations.
 - Experiments can test the veracity of theories.
- **Simulation Method: For**
 - the systems that is under invention or construction.
 - complex phenomena that cannot be implemented in laboratories evolution of the universe, such as astronomy, physics or economics
- **Theoretical Method:** the classical methodology since they are related to logic and mathematics. Theory is important to build methodologies
 - To develop logic and semantic models and
 - To reason about the programs in order to prove their correctness
 - To the design and algorithm analysis in order to find solutions or better solutions (performance issues, for example).

Research Process (Methodology)

- Initial Idea
- Background Investigation
- Refinement of Idea
- Core Work
 - Investigation and Development
 - Documentation
 - Prototype (if appropriate)
- Evaluation
- Identification of Future Work
- Presentation





Initial Idea

- Stems from critical thinking
- Be on the lookout for and open to seeing problems
 - Gaps in framework
 - Repetitive behavior that's slightly different (and can be generalized)
 - Manual solutions (that can be automated)
 - Inelegant solutions
- Ask questions
 - “Is something missing here?”
 - “Can this be done in a better way?”
 - “Is there a need for a new approach?”
- Should be an area you're interested in, as:
 - You'll be spending a lot of time with it
 - It won't always be easy/fun to continue...

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Background Investigation

- Given an idea, need to determine:
 - Has this work been done previously?
 - What similar work has been done leading up to this point?
 - How is any previous work distinguished from what I'm planning to do?
 - What group of people will be positively impacted by the research?
- Tools
 - Literature Review using library resources (e.g. online databases such as ACM and IEEE, popular magazines)
 - WWW search

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Refinement of Idea

- Based on background investigation, need to refine idea
- Issues:
 - Precision – focus on precisely identifying:
 - Problem
 - Possible solutions (plural!)
 - Scope – need to “build fences”
 - What’s an essential part of this work? (fence in)
 - What’s tangential, additional, or for any other reason best left for later/someone else? (fence out)



Core Work- Investigation and Development

- Provide yourself with infrastructure
 - equipment / software
 - additional knowledge (“get up to speed”)
- Do the work
 - Experimentation (scientific process)
 - Develop opinions
 - Look for better ways of solving problem
 - Can you generalize?
 - Can you develop a framework?
 - Discuss, brainstorm
 - Reevaluate as you proceed
 - Look for improvements, changes to your original ideas



Core Work- Investigation and Development (2)

- **Process**
 - **Work regularly**
 - Easier to keep going if have a commitment to a regular work time
 - Helps you keep your past work in mind
 - **Allocate large block of time for research**
 - Takes time to get going/back to speed
 - Make sure can do something significant each work session



Core Work- Documentation

- **Need to document as you go**
 - Don't want to lose any information
- **1) Maintain a journal for day-to-day thoughts**
 - Can be paper, electronic, ...
 - Keep it with you at all times
 - Never know when good ideas will hit
- **2) Keep an updated task list**
 - Focus on accomplishing something each work session
- **3) Write up your work**
 - Periodically, write a few pages on a subset of your work
 - Summarize work, accomplishments, problems
 - At end, write up a summary document
 - Can be based on steps discussed here



Core Work- **Prototype**

- Need to demonstrate the merit of your ideas
- If work is non-theoretical, do this through a developed system
 - No need to build the entire system
 - Just need to demonstrate the value of the core ideas



Evaluation

- Perhaps the most difficult part....
 - Best if can show others are already using your work
- Quantitative
 - Test your prototype
 - What improvements exist over currently available alternative?
 - How much of an improvement do you see?
- Qualitative
 - What can you do now that couldn't be done before?
 - What are the benefits of your solution?



Identification of Future Work

- Helps you organize any future efforts
- Helps others build on your work
- Sources:
 - What you excluded in your idea refinement
 - New problems that have surfaced during your work



Presentation

- It's not a contribution to the field if no one knows about it or can use it
- Presentation/Dissemination
 - Conferences, Journals, Web
 - e.g. National Undergraduate Research conference
 - Papers, Talks, Poster Sessions
 - e.g. UWEC and UW System Research Days



Researching Skills

In this “Age of information”

- How to find the ‘**right**’ information
- How to evaluate it
- How to develop/improve it
- How to report it clearly and accurately
- How to make money out of it

Searching Skills

Reviewing Skills

Engineering/Scientific Skills

Writing Skills

Searching Skills



One Fundamental Aspect of Research is “Asking Questions”

- As many as one can...
- Framing Questions
- Identifying Sensible/Meaningful/Useful/ Relevant/ Important Questions
- Investigate those questions
- Report those questions

Asking Sensible Questions

W5H2 Analysis

- (What) to find the information
- (Which) to evaluate it
- (Where) to report it clearly and accurately
- (Why) How to improve it
- (When) How to make money out of it
- (How)...
- (How Much)...

