IT513G: Research and Development

F2: Research and Development

(And what to think about for your final year project)

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University of Skövde

Overview

What is Knowledge and how do We Acquire it?

Research and Development

Design-Science

Final Year Project Advice

What is Knowledge and how do We Acquire it?

What is Knowledge?

> ***"Knowledge is an unending adventure at the edge of uncertainty."*** *Jacob Bronowski*

Knowledge is valuable

- "The advancement and diffusion of knowledge is the only guardian of true liberty." James Madison
- "They know enough who know how to learn." Henry Adams
- "Real knowledge is to know the extent of one's ignorance." Confucius
- "The person who knows how will always have a job. The person who knows why will be that person's boss." Linwood Rose

Where do we get knowledge?

- How do we separate knowledge from facts?
- How do we separate facts from claims?

Facts, Interpretations, Claims, and Opinions

- Facts are **indisputable**
- Understanding and interpretation of facts can be debated
- **Example**: A political party leader gets married
  - Fact: Other political party leaders and government ministers attend the wedding
  - Fact: A known criminal gang leader also attends the wedding
  - Interpretation: "There is a security risk"
  - Claims:
    - "Didn't know" there was a gang connection.
    - He's a "Superficial acquaintance"
  - Opinion: "The politician's career is over."
- We can form our own opinions, but **not** our own facts
- Facts, interpretations, claims, and opinions **must** be separated

Six Ways to Acquire Knowledge

1. **Tenacity**: Knowledge based on superstition or habit
2. **Intuition**: Guesswork - not based on reasoning or inference
3. **Authority**: Accepted because it comes from a respected source
4. **Rationalism**: Acquisition of knowledge through reasoning
5. **Empiricism**: Acquiring knowledge through experience
6. **Science**: Testing ideas empirically according to a specific testing procedure that is open to public inspection

Note that this is one classification of knowledge acquisition. There are others.

Tenacity

Tenacity: Knowledge based on habit or superstition

- Examples:
  - “Good research can only be done by those in their 20s.”
  - “OO design has too many subroutine calls and is too inefficient.”
  - “Java is too inefficient for real use.”
- Exposure: The more we see something, the more we like it
- Tenacity has:
  - No guarantee of accuracy
  - No mechanism for error correction
- Knowledge from tenacity is unfounded (has no basis)

Intuition

Intuition: Knowledge acquired as an immediate understanding or insight that occurs without deliberate reasoning or empirical evidence.

- Examples:
  - I think he is a nice person
  - It's probably going to rain today
- We do not really understand why we believe it
- Spontaneous and often a product of subconscious mental processes
- No way to separate accurate from inaccurate knowledge
- Can be used to form hypotheses
- Can be very misleading

Authority

Authority: Information or beliefs that are accepted as true based on the credibility or status of the source

- Examples:
  - Religion
  - Totalitarian government
  - Rules or knowledge our parents taught us
- No way to validate or question the knowledge
- Not the same as asking an expert
  - We can accept, reject, or challenge an expert
  - Teachers are *experts, not authorities*

Rationalism (Reasoning)

Rationalism: the primary source of knowledge is reason, rather than sensory experience.

- Logical deduction
- Assumes knowledge is correct if the correct reasoning process is used
- Important for development of theory and pure maths
  - A *mathematical proof* is an example of rationalism
  - As is theoretical physics
- Easy to reach incorrect conclusions
  - False premises
  - Mistakes in the reasoning, or steps skipped
- Rationalism can be used to arrive at a hypothesis
  - Hypothesis can then be tested with the scientific method
  - e.g. experimental physics

Empiricism

Empiricism is a philosophical approach asserting that knowledge is primarily derived from sensory experience.

- "I have experienced it, therefore it is true."
- Experience is *subjective* and hard to control
  - Can vary with mood (affect), for example
- **Example**: "I wrote 3 programs without designing and they worked — designs are worthless!"
  - Who wrote them?
  - What programs?
  - Were the problems trivial or complex?
  - Was the design present but just unwritten?
- Much of computer "science" can be considered to be empiricism.

Science

"A branch of study that deals with a connected body of demonstrated truths or with observed facts systematically classified and more or less comprehended by general laws, and incorporating trustworthy methods (now esp. those involving the scientific method and which incorporate falsifiable hypotheses) for the discovery of new truth in its own domain."
Oxford English Dictionary

- Based on objectively observed evidence
- Science requires:
  - Method
  - Rigour
  - Openness
  - Honesty
  - Scepticism

Research and Development

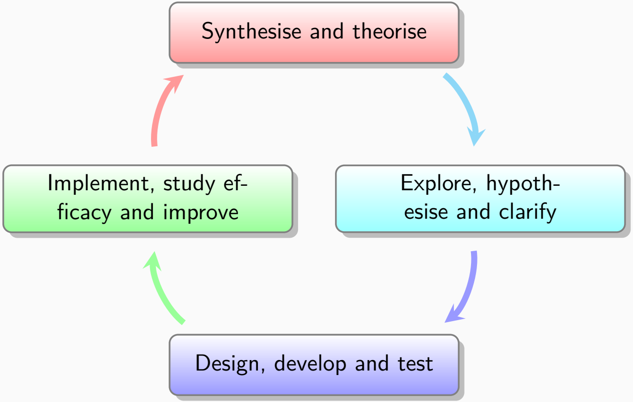
Research and Development: Definitions

- **Research** always aims to **build knowledge**
  - Establish or confirm facts, reaffirm the results of previous work, solve new or existing problems, support theorems, or develop new theories
  - Should answer a question that is **relevant & interesting** for the area
- **Development** aims to **build services or products**
- R & D is an investment for a company or organization
  - The first stage of development of a potential new service, product, or process
  - No immediate profit, but high risk
  - Usually conducted by a specialized organizational unit
    - Often together with academia in joint or co-funded research projects

Research and Development Carries Uncertainty w.r.t. ROI

- Innovation of new products
- Re-use of innovations
  - Re-purpose
  - Re-package
- Studies show: companies with persistent R&D outperform other companies
  - Even stronger correlation for high-tech industry
  - Hence, R&D investments are in the long run critical for competition
- Difficult to manage
  - No advance knowledge on how to accomplish the desired result
    - Nor how to solve the problem
- Risky to finance
  - Will it be possible to get a profit out of the results?

Reseach and Development Cycle



1. Develop theory
2. RQs and hypotheses
3. Prototype solution
4. Experiment or case study
5. Refine theory
6. New RQs and hypotheses
7. Refined prototype
8. New experiment ...
9. Accept or reject

Design-Science

Design-Science as a Research Paradigm

- Development and performance of (designed) artefacts.
- Explicit intention of improving functional performance of the artefact.
- The artefact could for example be an algorithm, a model or a tool.
- 7 guidelines.
  1. Design as an artefact.
  2. Problem relevance for industry or business.
  3. Design evaluation via well-executed evaluation methods.
  4. Research contributions must be clear and verifiable.
  5. Research rigour in both the construction and evaluation of the design artefact.
  6. Design as a search process by utilising available means while satisfying laws in problem environment.
  7. Communication of research.

Design-Science: Iterative Processes

Relevance	**Artefact**	**Knowledge**
To stakeholders	Problem definition	Publications
Managers	Theory	Theories
Engineers	Research questions	Tools
Industrial Environment	Hypotheses	Methods
...		

- **Literature study** to define problems and approaches
- **Controlled experiment** to develop artefact
- **Case study and interviews** to evaluate artefact
- **Dissemination**: publication of knowledge

Common paradigm for PhD projects with industry partners

Final Year Project Advice

What to Think About for the Final Year Project (1/2)

Important!

You're ***not*** supposed (*or expected*) to do a full-blown design-science project.
The final year project is ***not*** a development project.

Your main task for the final year project is to demonstrate that you've achieved the learning goals.

1. Plan and execute independently a project within a given time frame;
2. Identify, formulate, argue for and solve or answer a scientifically grounded problem or question within the field of informatics;
3. Choose, argue for and apply a suitable scientific method to solve the problem;

What to Think About for the Final Year Project (2/2)

4. Explain and apply research ethical principles;
5. Reflect on the result in relation to the chosen problem or issue and position the result in a larger context, including both scientific, ethical, and societal aspects;
6. Orally present a report and serve as critical reviewer of the contents of other people's work; and
7. Produce a written report that clearly and concisely describes the work carried out.

- Product is "nothing" — building knowledge is everything
- Demonstrate that you understand how to undertake a research project

Independently Plan and Execute a Project Within a Given Time Frame

- **Plan**
  - Identify the necessary activities
    - Literature, problem formulation, study design, study execution, data collection…
  - Allocate time for each activity – including extra time for e.g.
    - Unexpected issues
    - Iterations on the report
  - Set up and test any tool that you plan to use before you start
    - Not all available tools deliver what they promise
- **Execute work independently**
  - DVSUG students work in groups, but are responsible for their own parts
    - … and your individual contribution will be examined
- **Finish in time**

Identify, Formulate, Argue for and Solve or Answer a Scientifically Grounded Problem or Question within the Field of Informatics

- **Identify a scientifically grounded problem or question**
  - Need papers supporting that the problem or question is of interest
- **Formulate the problem or research question**
  - The better it is formulated the easier the study is to design and evaluate
  - Not all problems are research problems
    - e.g. if you know the solution then it's not a research problem
- **Argue for the problem or question**
  - The papers support your argumentation, but you still need to provide the arguments
- **Solve or answer the problem or question**
  - Hence, the problem or question must be well expressed since the outcome is unknown

Choose, Argue for and Apply a Suitable Scientific Method

- **Choose a suitable scientific method to solve the problem**
  - The problem or research question should be formulated so that it is independent of the method
  - Several methods might be possible to use — pick the best w.r.t.
    - Most feasible within time limits
    - Most likely to solve the problem or answer the question
- **Argue for a suitable scientific method to solve the problem**
  - You should not just pick a method – you should discuss the pros and cons of all **relevant methods** and show that your choice is reasonable
- **Apply a suitable scientific method to solve the problem**
  - You need to show that you can use the method with scientific rigour
    - No shortcuts — check all steps with your supervisor before implementing them
    - But keep in mind you are still responsible for your choices

Reflection, Context and Positioning

- **Reflect on the result in relation to the chosen problem or issue**
- **Position the result in a larger context**, including:
  - Scientific aspects
  - Related work – compare and contrast with similar work
    - Same problem, same or similar approach or otherwise related
    - What is similar and what differs
- **Ethical aspects**
  - What are the relevant ethical aspects and consequences (as-is or if continued)?
- **Societal aspects**
  - What societal impact might your work have (as-is or if continued)?

Other Goals

- **Explain and apply principles of research ethics**
- You need to **identify relevant ethical issues** and show how you handle them
- You need to **identify relevant threats to validity** and show how you handle them
- **Orally present a report** and **serve as critical reviewer** of the contents of other people's work
- **Produce a written report** that clearly and concisely describes the work carried out.

All will be covered in the remaining lectures and the assignments

Kritisk Granskning

Perspective

There are two fundamental questions that we should ask

1. How do I recognize **quality papers**?
    - Is this a paper I can trust? Can I base my work on the authors conclusions?
    - This is a question of assessing the level of quality of given information
2. How do I know I **covered** the relevant literature?
    - Will my planned work be interesting? Have I cited the ones that deserve it?
    - This is a question of using the right methodological approach to cover a field

- It’s a waste of time to continue work based on other’s questionable results
- There’s no point in inventing the wheel twice
- It’s rude to not give credit to those who actually did the work

Recognizing Quality Literature

Science relies on **peer reviewing**

- A number of **experts evaluate the paper** and give a verdict accept/revise/reject
- Often a **score sheet** or checklist plus **comments** (written feedback to the author)

Example from a journal score sheet (STVR)

- Does the manuscript contain **new and significant information** to justify publication?
- Is the **problem significant** and concisely stated?
- Are the interpretations and **conclusions justified by the results**?
- Is the **summary (abstract) concise**?
- Are the **citations** adequate?
- Is the **writing** acceptable?
- Is the manuscript technically sound?

Types of publications (Decreasing Quality)

Perceived Quality (estimated acceptance rate) - International better than regional or national

Journal	(2-5% Can be very general e.g. “Science” or cover an area)
Conference	(<10% Covers an area e.g. Conference of Software Engineering)
Workshop	(30-40% Smaller area e.g. Automated Software Engineering)
Symposium	(20-80% Very small area e.g. Open Collaboration)

Peer Reviewed Anthology
Specific work with special standing (e.g. Most cited article from Skövde by Tarja Susi).

Short Paper / Poster / Panel
Other Books / Articles
White Paper / Technical Report
BSc / MSc Thesis
Blogs / Wikipedia etc (if article cites reference we go to reference)

Article Type (Increasing Quality)

- Position paper, Vision paper (Qualified Guess / Vision)
- Technical note (Basis for Technology - Short)
- Technical paper (Detailed Technical Discussion - Longer)
- Research paper (Has a method and often includes a Study)
- Theory research paper (Theoretical Framework)
- Case Report or Case Study (Specific case of Applied Technology)
- Survey paper (up to Hundreds or Thousands of articles systematically reviewed or compared)

Increasingly complex method with increasing confidence

Proof of Concept / Proof of Principle	**Existence** is shown
Observation study	**Observe and Correlate** - Causality not guaranteed
Control Group Study	Group and Control Group
Experiment	Experiment with Hypothesis and **Measurements**
Quasi-Experiment	**Less Random Variation** in Experiment
One Off Experiment	Random Variation but at one Time
Longitudinal Study	**Repeated** over (long) Time, retrospective / prospective
Case Study	Depending on **reality** and thus less variation
Literature Survey	With or without Search Criteria and Evaluation Criteria
Meta-Study	**Study of Studies** - Can be thousands of scientific papers

What can we rely on to judge papers?

Rule of thumb: Journals have more quality

- Some journals and conferences are **predatory** and would also publish anything
- Some **conferences** and workshops have very **high quality** papers
- **New findings** have not yet reached the journals (take years to publish)
- Some low quality papers can **slip through** in spite of a good peer review process

Rule of thumb: Many citations indicate that the work is trusted - BUT

- Citations **accumulate over time** so how compare new and old papers
- Some papers are **easier to access** and thus cited more often
- The **size of the field** affects the number of citations
- Chosen **venue and key words** have a great affect on how easy the paper is found
- Some authors apply extensive **self-citations**

Fake journals and conferences

There are journals and conferences that are not real scientific conferences / journals. There only **appears to be peer review**

Names sound like real conferences but only purpose is to make money on **conference registrations or publication fees**

One-off conference that are cancelled (may be real but target group may be too small)

It can be very complicated to differentiate between a fake journal/conference and a real conference

Read about the Sci-gen scandal: http://en.wikipedia.org/wiki/SCIgen

Fake conference Organizers

-

Their work is to organize fake conferences and earn money

[BioC] Fake Conferences CSCI and WORLDCOMP

rickardbrown at hushmail.com rickardbrown at hushmail.com
Tue Dec 24 18:44:02 CET 2013

- Previous message: [BioC] RleList
- Next message: [BioC] BSmooth install question
- **Messages sorted by:** [date] [thread] [subject] [author]

```
Fake Conferences CSCI and WORLDCOMP of Hamid Arabnia


Ha[redacted] A[redacted] from University of Georgia is well known
for his fake WORLDCOMP conferences
https://sites.google.com/site/dumpconf  This website
has an open challenge posted sometime in 2012 and it
also has comments from several well-known researchers
on WORLDCOMP.Ha[redacted] A[redacted] never responded to these
because his conferences are bogus.


Ha[redacted] A[redacted] (the money hungry professor) has
recently started 2014 International Conference on
Computational Science and Computational Intelligence
(CSCI'14) http://www.americancse.org to deceive
researchers further. CSCI'14 is started under the
title of "American Council on Science and Education"
which is a dummy corporation (does not exist anywhere
in the world). Ha[redacted] A[redacted] buried his name in the
list of names of other innocent steering and program
committee members of CSCI'14 to avoid any special
attention. He knows that if his name is given any
special attention then researchers immediately notice
that the conference is fake due to his "track record"
with WORLDCOMP. Ha[redacted] A[redacted] (Guru of Fake
Conferences and champion of academic scam) spoiled the
reputations and careers of many authors who submitted
papers to his infamous WORLDCOMP for more than a
decade and he is now ready to do the same using CSCI.
```

Warning Signs

Here are some warning signs but note that bona fide conferences may show some of these warning signs; in particular many reputable conferences are held in nice places.

- The conference is advertised using **spam**
- The conference has the **same chair every year**. (Bona fide conferences may have the same people on an executive committee for many years, but probably not the same chair.)
- The call for papers emphasises repeatedly that it is a **"reputable"** conference with many **"famous experts"**
- The call for papers, and subject of the conference, is **very general**
- The chair has **chaired dozens** of other conferences but probably has few good publications and does not work at a reputable institution
- The conference is in a very **nice place**

(från University of Bristol)

Why do fake an article

Paper has flaws

- Writing is bad
- Technical artefact is lacking
- Bad Result / Execution / Method

Good paper

- Narrow area / Area no longer very active
- Hard to get In

To get a **degree** or a **promotion** you must publish a **certain number of papers**. And if you can not get in within a reasonable period…

National or regional conferences / Journals are an alternative - **how do we know peer review happens**?

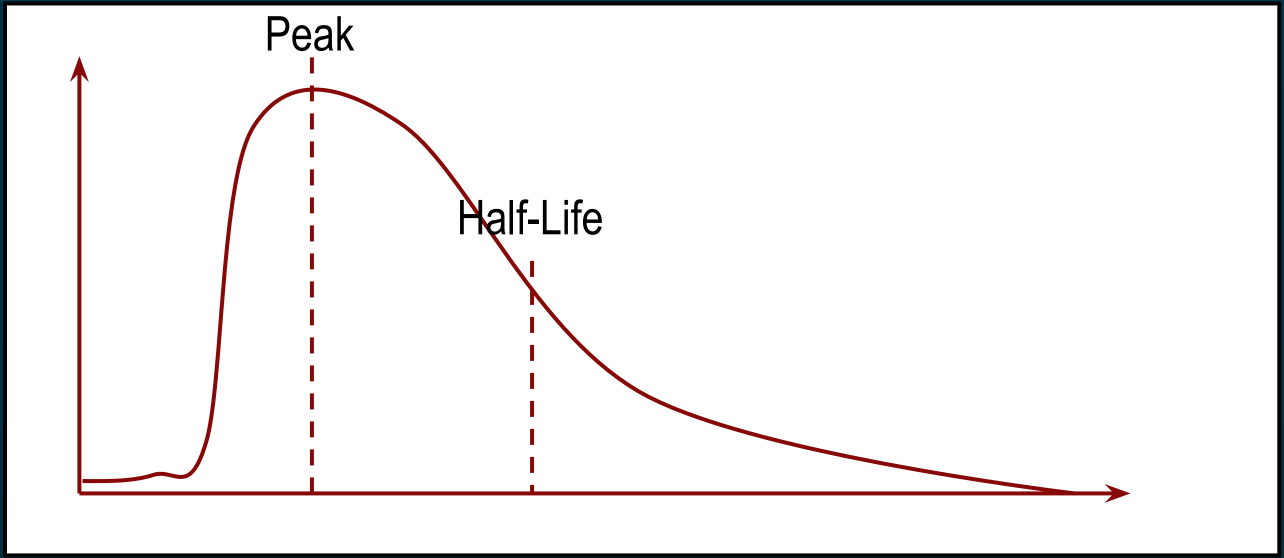
Ranking

Impact – Number of Later Journal Papers Citing this Paper

Speed – How fast other papers cite the paper

Half-life – How fast citations taper off

Rankning according to indices such as Science Citation Index / Social Science Citation Index



New and significant information

Research is about building knowledge / **New information**

Every paper should contribute with some new knowledge

- Defining a **new problem/solution** that hasn't been properly defined and discussed before
- **New application**/evaluation of a solution for a problem or applied to a distinct problem
- In many cases only some aspect that is new
- Significant information
- Usually relatively **small increments,** sometimes big leaps or paradigm-shifts
- But it's not a contribution if it's **not useful or important** to anyone
- Results should be **generalizable** - statements on contribution and related work

But it's not a contribution if it's already been done and no new knowledge is provided

Problem statement

There should be an overall description of the problem and its implications

- To give a **motivation** explaining why it's important to address
- The problem should also have
  - **Problem definition** or statement
  - A short statement focusing on whether we had a **solution for before the study**

Research questions

- **Precise questions** to be answered by the study
- **Hypotheses**
- **Expected results**, what to test

Results are Justified

Results should be **presented clearly**

Collected data should be **summarized and visualized** in tables and/or diagrams

Ideally the raw collected **data** is also **available** but this is rare

Analyzed and interpreted

Trends, anomalies in tables and diagrams should be identified and discussed

Supporting the **conclusions**

Some authors read in too much in the results and draw **too strong conclusions**

Wishful thinking, expectations or prejudgments

Compare the stated **conclusions** with the **results**

Referencing / Citations

Important when giving a verdict on whether to publish a paper or not - Requires field expertise

- The source of any statement, claim, description etc. should be **cited**
- Unless it's something new for the paper in which case it should be **motivated**
- **Number of citations** is used as metric when evaluating researchers
- Giving credit to a researcher who deserves it is not just polite – it's necessary
- Giving credit to a researcher who doesn't deserve it is related to plagiarism
- Inadequate or wrong citations reveal a lack of knowledge of the field

Is the study technically sound?

Reveals the author’s field expertise

- Definitions, Terminology, explanations and descriptions given in the background
- How well does the study suit the problem and to what extent is the design described
- Are relevant validity threats identified, accounted for and mitigated by design?
- Is the Execution of the study any good?
- Is Data collection sufficiently rigorous?

A flaw in the study means that it cannot be trusted

Presentation

- Language
- Flow (narrative thread)
- Structure
- Pedagogic explanations
- Useful figures, graphs and tables
- Worth to note is that poor presentation doesn't imply a poor study or questionable results

What Does Data About Papers Look Like?

Is paper usable or not? Can we find the paper again?

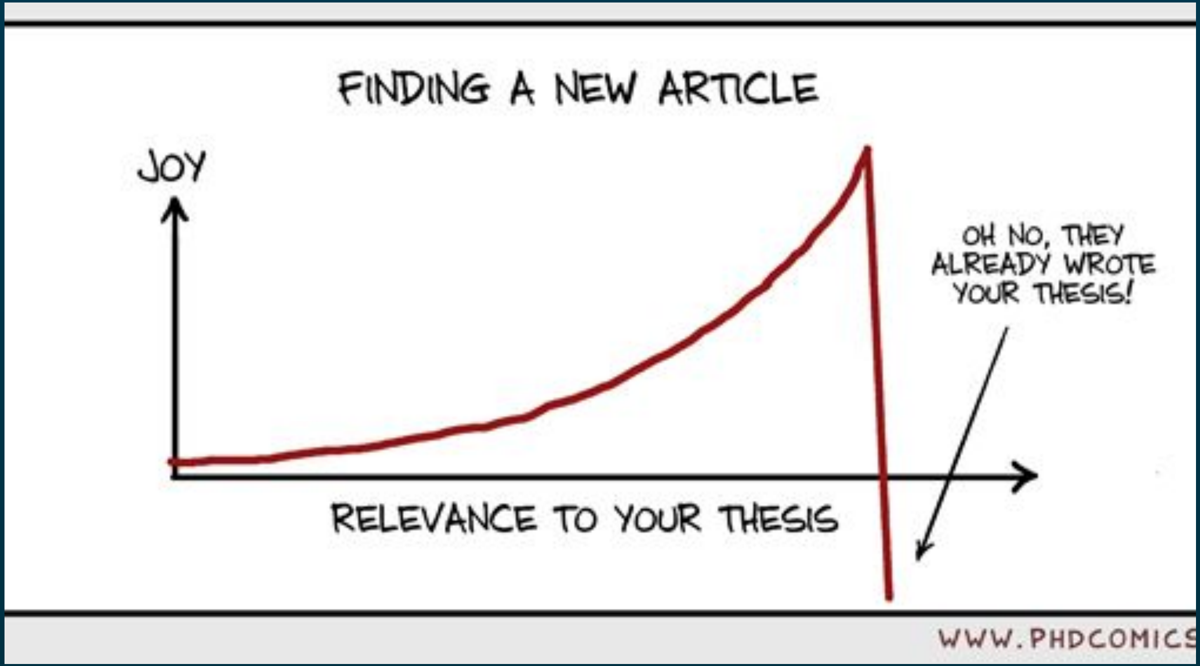
Anything missing? Hyperlink?

The first paper has a few red flags.. Can we add more data to make it even clearer?

Title	Year	Venue	Pages	Publication	Category	Place	Method	Citations	Publisher
CLPL: A Self-supervised Contrastive Learning Pseudo-Lab	2022	CSCI 2022	7-12	Conference	Short Paper	Las Vegas	Proof of Concept	0	IEEE
Management of Implicit Requirements Data in Large SRS D	2022	SIGMOD Record	18-29	Journal	Paper	-	Proof of Principle	1	ACM
An Investigation of confusing code patterns in JavaScript	2023	Journal of Systems and So		Journal	Paper	-	Experiment	2	Elseveir

Finding Papers

Even if you find a paper that does nearly exactly the same as you are intending you can always add to the future work or repeat the study with new conditions



Finding Papers

Strategy depends on your goal

Find support for e.g., a statement or your description of x

- You might just need one if you are looking for a source supporting a statement
- It should include the one that first described x in similar way and more is better

Give examples of research on x

- Related work must recognize and cover all the areas including examples
- It should be clear from the text that the list is not exhaustive in case it isn't

Give a complete overview of research on x

- Literature survey should be complete within its defined scope

Strategies

Systematic literature survey (SLR)

- Search databases using search terms with Narrow scope – complete picture
- Scoping is essential since this can grow fast

Mapping study

- Search databases using search terms with Broad scope – less detailed than an SLR
- Exploring a field

Snowballing

- Start with one or a few key papers
- Follow citations forward and / or backward
- Identify a research community – a set of relevant Papers / Conferences / Journals

Planning the Systematic Literature Survey

Identify the need for an SLR

A researcher’s need to understand the state-of-the-art in an area

Are there recent and complete reviews available?

Specify the research questions

Need to be well defined and specific

Determines which papers to analyze, which data to collect and how to analyze it

Fuzzy RQs leads to inconsistent / incomplete data and questionable results

Develop the **review protocol**

Defines the procedure

Including e.g., **search strategy**, **selection criteria** and data extraction strategy

See Wohlin et al. (2012) for details

Acts as a log (living document)

Executing the SLR

- Identification of research
- Specify **search strings** and apply to **databases**
- Search other sources (web sites, tech reports, theses...)
- **Apply snowballing**
- Selection of primary studies
- Inclusion and exclusion criteria, developed beforehand but perhaps adjusted
- Iterative process based on manual judgement
- **Quality assessment of selected studies**
- Important if contradictory results
- Data extraction and monitoring
- Form based on the RQs, filled in by at least 2 researchers
- Data synthesis
- For example, visualization of the collected data in tables, graphs, statistics etc.
- **Tell a story** to answer the RQs

Mapping Study

Sometimes called a scoping study

Follows the same steps as an SLR but is a better choice when

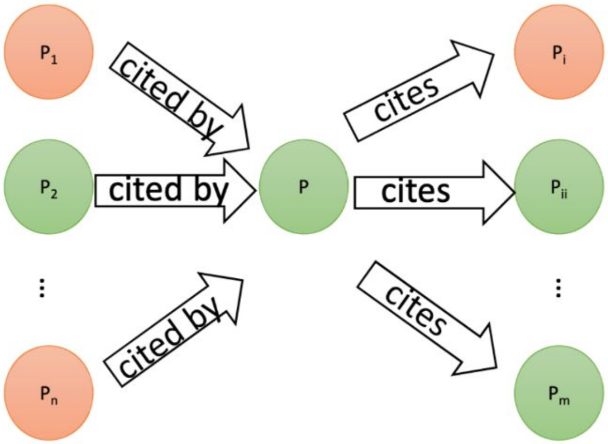
- The research question is broad
- The field is relatively unexplored

Gives an overview of the state-of-art or state-of-practice

- Analysis tends to be more quantitative in a mapping study than in SLR
- But it still has to relate the findings with real-world needs

Snowballing

- Assumption: Researchers in the field know their field and who to cite
- Prerequisite: At least one key /central paper in the field



Formulate your focus (RQ)

```
Mark the key paper(s) as green
While unexplored green papers DO
  Set one as current
  Check all new papers in reference list for current
  Check all new papers citing the current paper
  Mark each checked paper as relevant (green) or irrelevant (red)
  Mark current as explored
```

Green set of papers are now only citing or cited by papers already explored or red

How many references are needed?

Problem area & research questions

- A few good and not too old papers supporting your arguments are sufficient

Background

- Whenever you state a fact you need a reference supporting it
- But you don’t need to find all papers supporting it – coverage is irrelevant

Conclusions & contributions

- You need to recognize papers for related work and relate it to your own, e.g.
- Researchers [refs] have addressed, presented or ... – then describe the relation to your work
- E.g., same problem, similar technique or ..., followed by something you do different

For your essay (or final year project) complete coverage is not needed

- At least one good source for each part - coverage is irrelevant
- Your job is to discuss e.g., validity threats in relation to your work and its value

Kritisk Granskning av Två Artiklar

Skriva Summaries och Förbereda Presentation av Båda Artiklarna. Personer väljs slumpvis per artikel. Ibland hinner vi mer än en presentation per artikel.

- **Introduction** with an example of use of the results as well as the problem area
- **Background** emphasizing important theories, models, key concepts, challenges, opportunities and risks.
- **Problem**, covering e.g., problem area, statement, research question, hypothesis
- **Methodology** covering research method and approach, including your description of article classification
- **Result & contributions** - Are the results valid, contributions significant and repeatable, including publication of program code
- **Ethics & threats to validity** - Is the article unscientific or somehow unethical including the venue of publication? Are the authors self-referencing or are there few citations to the article (for symposium we expect lower number of citations)?

IT513G: Research and Development

F4: Research Methods

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F4: Research Methods

University of Skövde

Overview

Types of Research

Philosophical Positions

Relevant Research Methods

What is a “Research Method”?

The word *“method”* can be used in different ways depending on research area

- **Not** a *method* according to definition used for the final year project
  - Approach or technical response or solution to the problem
  - Process and how you implement the approach
- *Method* according to definition used for final year project
  - Evaluation method
  - Investigation method
  - Scientific method
- Examples of methods according to definition for final year project
  - Survey, experiment, case study ...
  - Note that how the method is applied is part of the approach – not the method

Types of Research

Descriptive (or statistical) Research

- Purpose: to show, e.g.
  - Current state
  - Historical trends
- Collect numbers and produce statistics
- Example questions:
  - Which areas of Sweden do students come from?
  - Which countries do exchange students come from?
  - How has the number of international students changed over the last two decades?
  - How has the proportion of international students changed over the last two decades?
  - How has the country of origin of international students changed over the last two decades?

Types of Research

Analytical Research

- Purpose: to evaluate facts critically, e.g.
  - Given the current state and historical trends — what can be predicted?
  - What does this data mean?
  - How does it compare to related work?
- Descriptive research is usually followed by analytical research
  - Necessary for conclusion and discussion

Applied Research

- Driven by need
- Main purpose is to find a useful solution to a real and urgent problem
- Example questions:
  - How to improve production rate in car factories?
  - How to reduce food waste in restaurants?
  - Which algorithm is more cost-effective in solving problem X?
  - How can machine learning be applied to optimise job selection in a production environment?

Fundamental Research

- Driven by curiosity
- Main purpose to build knowledge
    - Although all research aims to build knowledge
- Does not necessarily solve any real problem
- Example questions:
    - How did the universe begin?
    - How can bumblebees fly?

Types of Research

Conceptual Research

- Purpose to describe or explain a phenomenon
- Defining concepts and building theory
- Examples:
  - How can we describe climate change?
  - What are the determining factors for a system's testability?
  - What gender differences are there in the ways software developers select and use tooling?

Empirical Research

- Purpose is to evaluate, e.g.:
  - Test a hypothesis
  - Observe the effect of a change
- Examples:
  - Can time clustering be used to optimise material flow in a supermarket?
  - Can constraint programming identify optimal solutions to complex scheduling problems?
  - Is there a correlation between A and B?

Types of Research in your Final Year Project (1/2)

The final year project will have elements of several research types, but there are no strict rules about which ones.

Most likely you will use:

- Empirical and applied; or
- Descriptive and quantitative

There will also be elements of:

- Analytical and qualitative
  - Results (data) must be understood, i.e.
    - Analysed and visualised
    - Interpreted and discussed
  - What is the contribution?
  - What does the contribution mean for e.g. society?

Types of Research in your Final Year Project (2/2)

Your final year project is, however, less likely to involve fundamental or conceptual research.

There is a lot of choice, so how can you choose a research method?

Remember from Lecture 2 that:

- "The problem or research question should be formulated so that it is independent of the method"; and
- You need to: "Argue for a suitable scientific method to solve the problem,"

How you formulate your research questions and select research method(s) depends on your *philosophical position* or stance

Philosophical Positions

Philosophical Positions

- **Positivism**: Knowledge must be based on observable facts
  - Precise theory and verifiable hypothesis
  - In SE research e.g.: Algorithm A gives better precision than B in solving X
- **Constructivism**: Knowledge cannot be separated from human context
  - Theory is tied to the context — sometimes the theory is local
  - e.g. in SE research:
    - How do developer team members think about and use a specific tool
    - Open source movement and agile processes

Philosophical Positions (2/2)

- **Critical theory**: Research is a political act since knowledge empowers groups of people
  - Research to help people or change a situation — often involving a targeted group
  - In SE research e.g.: open source movement and agile processes
- **Pragmatism**: Knowledge is approximate and incomplete
  - The value of knowledge depends on:
    - The method by which knowledge was obtained
    - How useful the knowledge is for solving practical problems

Philosophical Position Affects Choice of Research Methodology

- **Positivist:** Knowledge must be based on observable facts
  - Mainly *controlled experiments* – including *quasi-experiments*
  - But also *surveys* and *case studies*
- **Constructivist:** Knowledge cannot be separated from human context
  - Mainly *ethnography*, field studies
  - But also *exploratory case studies* and *surveys*
- **Critical Theorist:** Research is a political act
  - Mainly *case studies* and *action research*
- **Pragmatist:** Knowledge is approximate and incomplete
  - Any available method
  - Preference for *mixed methods*

Relevant Research Methods

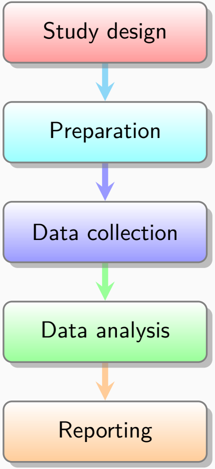
Relevant Methods for your Final Year Project

The following is not an exhaustive list of methodologies, but it covers what you most likely want to do:

- **Survey**
  - Collecting information from or about people
- **Case study**
  - Investigating an instance of a phenomenon in its real-life context
- **Controlled experiment**
  - Varying treatment and measuring effect
  - Other factors and variables are kept constant
  - Randomization of treatments applied to or by different subjects
- **Quasi-experiment**
  - Same as controlled experiment, but *no* randomization of treatments

Process is the Same for all Methods

- **Study Design**
  - Define objectives and plan study
- **Preparation**
  - Define procedures and protocols for data collection
- **Data Collection**
  - Execution of the study
- **Analysis of collected data**
  - Synthesise, visualise
- **Reporting**
  - Target audience, present, discuss



Controlled Experiment

Controlled experiments are typically undertaken in a laboratory or clinical setting.

- Randomised sampling of *treatment-subject* assignment
- Manipulate one factor while keeping other factors constant
  - *Independent variable* (IV)
- Measure – observe the outcome(s)
  - *Dependent variable* (DV)

A **quasi-experiment** is similar except that there is *no* randomization of treatment-subject assignment

Controlled Experiment

- **Precondition**: **a clear hypothesis**
  - The hypothesis is drawn from the theory on the cause-effect relation
  - The hypothesis guides *all* steps of the experimental design
  - Including which variables to use
- **Main challenges**:
  - **Sampling**: is the population representative?
  - **Control**: is there any other factor that might affect the outcome?
    - Possible **confounding factors** need to be understood; and
    - *Controlled* for, or explained.

Experiment: Planning

- **Clear idea of goal and hypothesis**
  - What to study and why?
  - *Cause–effect* relationship is important to know; *why* and *for whom*?
  - What do we expect? What does the theory predict?
- **Which variables to use?**
  - Independent (inputs) and dependent (outputs) variables
  - Which values can these take?
  - Determining the measurement scale
  - Choices constrain the statistical method(s) we later apply
- **Which subjects should we use?**
  - Representative distribution?
  - Randomization?

Experiment: Planning (2/2)

- **What needs to be prepared?**
  - e.g. preparation of objects, developing guidelines, defining measurement procedures
- **Test any tool you plan to use before you start!**
  - If feasible, practice data gathering.
  - Can data be gathered with the chosen tool and methods?
  - Using machine or deep Learning? Do you have time and resources to train and retrain models?
- **What are the potential threats to validity?**
  - Plan to avoid or to mitigate threats to validity where possible.
  - You can **never** avoid all threats to validity, but do your best and acknowledge what remain as *limitations* to your study

Experiment: Analysis (1/2)

- Use **descriptive analysis** to understand your data
  - Mean values, standard deviations, distribution etc.
  - Synthesise and visualise
  - Apply data reduction technique if appropriate
  - Apply a statistical test for the hypothesis
- **Interpretation**
  - Was the hypothesis confirmed or rejected?
  - What was the answer to the research question?

Experiment: Analysis (2/2)

- **Discussion** (not part of analysis)
  - What do the findings mean in terms of **contributions** and **potential impact**?
  - New or improved knowledge or technique ... ?
  - Who can use the results and new knowledge, and for what?
  - **Future work**: What further questions does this study raise?
- What are the **limitations** in terms of **reliability** and **scope**?
  - Can we **trust** the results and to what extent can we **generalise** them?

Case Study

Case study can be used when experiment is less appropriate

Case studies have *multiple* applications in software engineering research where:

- Context plays a role
- Effects are wide-ranging or take a long time to emerge
- Observations of parts of a problem space do not explain the whole

Precondition: A clear purpose

- **Purposeful sampling** rather than randomised
- i.e. select cases that fit the purpose - sometimes one case is enough

NB: **"Case study" is a term that can be misused.** When some people use "case study" they mean "*the study of a case*" — being able to recognise the difference is a useful skill.

Case Study (2/2)

Main challenges:

- Selection of case – is it typical (or maybe critical to the purpose)?
    - **Unit of analysis** is e.g. a company, a project, or a team
    - To what extent can the results be **generalised**?
    - **Reliability** – is the research reliable?
- Level of control is *low*
    - Case studies are observational rather than controlled
    - Case studies are *multi-faceted*:
        - More than one investigative method: e.g. surveys, interviews, observation;
        - Multiple data sources: e.g. documents, processes, products, people, ...;
        - Often quantitative and qualitative analysis are both used; and
        - **Triangulation**: How can information gathered from multiple sources by different methods be used to tell a clear and consistent story? Are anomalies and inconsistencies important or explainable?

Case Study: Planning

- **Objective**: What is it you want to achieve?
  - Explore, describe, explain, improve ...
- **The Case**: What is to be studied?
  - You need a solid baseline to avoid bias and ensure internal validity
  - Company baseline: Historical data from standard projects
  - **NB**: *Such data introduces limitations on the research questions*
  - Sister project: Both must have the same characteristics
- **Research questions:** What do you want to know?
  - What type of data do you need to answer the question?
- Where and how will you collect the data?
- "Tactics" to reduce validity threats

Quantitative data analysis

- Much like experiments
- Descriptive statistics, e.g.
  - Mean values, standard deviations, histograms, scatter plots ...
- Correlation analysis, e.g.
  - To relate measurements from old and new process activities
- Hypothesis testing
  - Cause – effect, using independent and dependent variables

Case Study: Analysis (2/2)

Qualitative Data Analysis

1. Data is coded: code based on patterns, themes, phrases ...
2. Each piece of text is classified with one or more codes
3. Groups & subgroups used to create a code hierarchy
4. Hypothesis is formulated
5. New study is planned to confirm or reject hypothesis
6. Data is collected and the iterative process continues

Survey (1/2)

Survey: Collecting information from or about people

- In retrospect, after the implementation of something; or
- Early-on to understand a problem in its context.

Questionnaires and (semi-)structured interviews

Precondition: A clear research question about:

- The nature of a target population; or
- The knowledge and opinions of a target population.

Survey

Main challenges:

- **Sampling**: Is the population representative?
  - Selection of subjects and response rate
- **Design of questions**: Will the answers be useful and valid?
  - Which questions to ask
  - How to formulate the questions
- **Number of questions**
  - Quality of answers might decline with many questions
  - Harder to analyse surveys with many questions

Survey: Planning

The purpose affects the nature of the questions

- Descriptive or explanatory
  - Determine the distribution of certain characteristics in some population
  - Explaining why the distribution is as it is

Interviews or questionnaire – pros and cons

- Interviews are time-consuming to do and to analyse, but gives high response rate and few "don't know" responses
- Questionnaires are less time-consuming, but may not always be completed

Survey: Planning

Focus on a few important variables – critical for the research question

- Questionnaires can provide a lot of variables – mind the complexity
- **Plan for the analysis and synthesis when you design the questionnaire**

Select the sample with care

- Are the respondents representative for the entire population in focus?

Questions should be clear and without bias

- No assumptions and no leading questions
- **Do not start data collection until your supervisor says go!**

Survey: Analysis (1/2)

Clear alternatives for the answers will give you quantitative data

- Straightforward statistics
- But no in-depth or elaborate answers, no nuances – just numbers

Free text or oral answers are harder to analyse

- You need to classifiy or categorise the answers – probably using a qualitative approach
- But answers might provide more information

Survey: Analysis

You also need to:

- **Synthesise**:
  - What do the results show when combining them?
  - Compare & contrast sub-groups
- **Visualise**:
  - Raw data is seldom a good way to communicate – tables and diagrams are far better
- **Interpret** with respect to research question:
  - What do these diagrams mean?
  - What is the answer to your question?

Your Final Year Project (1/2)

Keep the learning goals in focus and remember what it is you have to show:

- You can formulate and argue for a research problem or question
- You can argue for the relevance and importance of a research problem or question
- You can select and argue for a research method and approach to use
- You can apply the method in a good way (systematically & with scientific rigour)
- You can analyse the results and discuss them in a bigger or wider context

Nothing forces you to build a product or design a big experiment

- Scoping is essential to finish in time
- Don't design your study so that you are forced to build complex special tools for execution or data collection

Some advice:

- Test any tool you plan to use and adapt study design to what is feasible
- Document *all* design decisions and **discuss them with your supervisor before you proceed**

IT513G: Research and Development

F5: Problem Definition

IT513G: Research and Development

F5: Problem Definition

University of Skövde

Overview

What is a Problem?

Research Questions

Hypotheses

Aims and Objectives

What to think about for the Final Year Project

What is a Problem?

What is a Problem?

- It is a problem *iff*
  - It has a negative effect on someone or something important
  - The solution is not known
- "I'm hungry!" Is this a problem?
  - No! A problem has no known or obvious solution
- "My stomach hurts!" Is this a problem?
  - Yes, because the solution depends on what's causing it and the cause is not known although hunger could be causing it
- We have no tool to keep track of supplies! Problem?
  - No! The solution is known
- Our supply-chain is inefficient! Problem?
  - Yes, again the solution depends on the root cause and this is unknown although keeping track of supplies might be a way to find out

What is a Research Problem?

- Are all problems research problems?
- No! A research problem:
  - Has a negative effect;
  - Has no known solution;
  - Is interesting; and
  - Is researchable.
- Addressing a research problem contributes some **new knowledge**
  - Could be a very small contribution
- My stomach hurts! Can this be a research problem?
  - No, it's only interesting to me
- Our supply-chain is inefficient! Can this be a research problem?
  - Yes, but it should be generalised to *"inefficient supply-chains"*
  - By generalising the problem have stated a **problem area**

From *Problem Area* to a *Problem Statement*

- Problem area is broad
  - Consists of many contributing smaller problems
  - This is something that should be discussed to give a context
  - But you cannot solve them all in one study
- Thus, narrow it down to a research problem you can handle
  - Pinpoint one of the contributing problems
  - Describe and motivate your research problem
  - Who, what, when, where and why?
- Then express it as a problem statement or definition
  - Focused on what you plan to solve
  - 1 or 2 sentences well-defined description of the problem
  - A problem statement should not suggest any solution
  - It is *only* a definition of the problem

Problem: Example Structure (1/3)

One or two paragraphs describing the problem area
e.g. "testing is crucial … we need effective techniques … mutation is more effective than other criteria … mutation is computationally expensive … 90-99% of mutants are redundant … redundant mutants obscures benchmarking and do not contribute to analysis … avoiding redundancy would make mutation affordable for industry and benchmarking reliable … how to avoid redundant mutants while keeping the non-redundant … we do not know how to identify redundant mutants before analysis is completed … all suggested solutions have pros and cons …"
Context and motivation: unnecessarily high computational cost and proposed solutions are less effective

Problem: Example Structure

One paragraph describing your research problem
e.g. " ... most promising approach focus on mutant subsumption ... reduced ROR is one such approach ... reduced ROR is proven to subsume ROR ... lots of ongoing studies with reduced ROR ... reduced ROR implemented in tools ... all under the assumption that the subsumption is valid for strong mutation ... However, proof does not state strong or weak mutation but focuses on relational expressions and their immediate evaluation ... risk that this research field develops based on a false assumption ... "
Zooming in: one proposed solution claims to be effective, but there is an implicit assumption. Hence, the proof might not hold

Problem: Example Structure (3/3)

The problem statement or research question

"The reduced ROR mutation operator is considered to subsume ROR and therefore used instead of ROR by researchers and practioners. In most cases this is done together with strong mutation but the only proof that reduced ROR subsumes ROR is based on an implicit assumption of weak mutation and the correctness in a context of strong mutation is not known."

or: "Does reduced ROR subsume ROR in a context of strong mutation?"

Note that the problem or question is stated without any discussion of method or approach

Research Questions

Research Questions (1/2)

Your study is expected to answer the research question(s)

- **A research question (RQ) has to be:**
  - Well-defined
  - Fail safe
- **Well-defined**
  - Focused on one specific thing — i.e. a single question
  - You don't want to end up with a "yes and no" as your answer
  - Not open to interpretation
  - You don't want to end up with a "maybe" as your answer
  - If an RQ is difficult to answer, unclear, or imprecise — divide it into several, more precise questions that can be answered

Research Questions

- **Fail safe**
  - The goal of your study is to get an answer — *not* a specific answer
  - We all want our ideas to work but sometimes they don't
  - Research question(s) *must* allow for less successful outcomes
  - If the result is personally disappointing, or is negative, it can still make a contribution
    - Other researchers don't have to investigate the same idea for a solution
    - Other researchers could try a different or modified approach

Hypotheses

Hypothesis

A hypothesis is an *expected* result from your study

- The study tests the hypothesis to confirm or reject it
- Collected data implies yes or no
- Therefore, sometimes formulated w.r.t. the used measures
- i.e. as part of the study design

A research question sometimes requires more than one hypothesis

Example:

- RQ: "How do A and B compare in terms of performance"
- H could be "the performance of A differs from B", but performance has multiple dimensions and cannot be measured directly, so better to be specific

Hypothesis

- So, we can divide H formulating a hypothesis for each dimension:
  - H_1: A's average response time differs from B
  - H_2: A's average execution time differs from B
  - H_3: The error rate in terms of missed deadlines differs for A and B
- We might, for example, discover that the *null hypotheses* for H_1 and H_2 cannot be rejected, while H_3 is accepted
  - i.e. A and B are equally fast but A is better than B in terms of timeliness

Hypotheses for statistical tests are usually constructed as a pair: the *hypothesis*, which is the anticipated result of the treatment, and the (implied) *null hypothesis* that the treatment has no effect. Statistical tests are used to show whether the null hypothesis can be rejected.

Note: The RQ was fail-safe, so we have a clear answer.

Aims and Objectives

Aims and Objectives

Both the aim and the objectives are goals

- Aim is a higher goal – addressing the problem
- Objectives are more specific goals
  - What you need to achieve to reach the aim
  - Still independent from method (**what** to achieve – **not how**)

Example
Objective 1: identify potential candidate solutions for problem X
Potential methods: literature survey, questionnaires ...
Objective 3: compare candidate solutions w.r.t. Y
Potential methods: experiment, case study, interviews, questionnaires ...
Objective n: ...

Aims and Objectives

- When you formulate the objectives you should be able to argue that:
  - If you meet *all* objectives you have reached the aim
- When you're done you should be able to show the reader that:
  - You have delivered on all objectives; and
  - The decisions that you made, and their motivation.

Aims and Objectives can be used as a checklist that you can refer to in the discussion.
Useful to demonstrate and explain a systematic approach.

Putting it all Together

- Describe the problem area
- Zoom in on a description of your research problem
- Give a problem statement or research question
- State your expected result or hypothesis
- Your aim is to address the stated problem (or answer the research question)
- Your objectives are the things you need to achieve, e.g.
  - Select candidate solutions (objective)
  - Compare candidate solutions (objective)
  - Report the findings and discuss the implications of the results (objective)

Objectives expanded on next slide ...

Putting it all Together

Expanding the objectives:

- Select candidate solutions (objective)
  - Define the search area (where to look or who to ask)
  - Define criteria for candidates (how to identify them)
  - Search area and apply criteria
- Compare candidate solutions (objective)
  - Define comparison or evaluation criteria for the selected candidates
  - Plan a study focusing on selected comparison criteria
  - Prepare and implement the study
  - Collect the results
  - Analyse the results
- Report the findings and discuss the implications of the results (objective)

Putting it all Together (3/3)

- Now you just have to follow the plan and check that objectives are met
- Note that objectives are still method-independent while your approach is not
- In the “Approach” section of the report you specify the “how”, which is tightly connected to selected research method.

What to think about for the Final Year Project

What to Think About for the Final Year Project? (1/2)

- **Problem area**
  - This is a must and will also help you identify what's related work and what's background
- **Research problem**
  - This is a must and will help you scope your problem to something you can address by a limited study
- **Problem statement or research question**
  - One of these is a must — research question(s) are recommended
    - You already described the problem
    - It's usually easier to show that you've answered a question than solved a problem

What to Think About for the Final Year Project? (2/2)

- **Expected results or hypothesis**
  - Choice depends on the choice above
- **Aim**
  - Not strictly needed since process is fairly obvious
    (solve problem $\rightarrow$ answer question)
- **Objectives**
  - Very useful since:
    - Having an argument for each objective (and later its corresponding method) provides a solid argumentation for the entire study
    - Objectives *help you plan and keep focus* as they outline what you need to achieve in order to meet the aim
    - Objectives *help you communicate* with supervisor(s), examiner, opponent(s), readers, & audience

IT513G: Research and Development

F6: Experiment Design

IT513G: Research and Development

F6: Experiment Design

University of Skövde

Overview

Theory and Models

Experimental Design

Planning

Final Year Project Advice

Theory and Models

Theory/Model Assumption (1/2)

Theory: *A collection of related concepts, definitions, and statements that is a systematic description of a phenomena by defining specific relations between variables, for the purpose of explaining or predicting the phenomena under study.*

To build or challenge theories in SE we usually need a model

1. Model definition: A collection of attributes and a set of rules that govern how these attributes interact.
2. Model definition: A system of things and relations satisfying a set of axioms, so that the axioms can be interpreted as true statements about the system.

Theory/Model Assumption

A model is less complex than the real world

- The model assumption is that **necessary** properties are the same
- Necessary refers to the interpretations of the axioms
- Statements based on the model must hold for the real world

Experiment Situation

- Set of trials
- Trial: Subject (person)
    - Is subjected to treatments
- Treatment examples
    - Perform activity
    - Do test
- Measure: Instrumentation
    - Questionnaires, interviews, timing, physiological responses

Experiment Operation

- Both subjects and objects
- Subjects apply treatments to objects
    - e.g. student accesses two experimental web shops to see if they can distinguish the proper web shop from the fraudulent
- Subjects can also be subjected to treatments
    - e.g. one group of students gets an introduction to security prior to accessing the web shops

(Quasi-)Experiment Operation

- No subjects
- Simulate something (completely or partially)
    - Apply treatments
        - e.g. in web server performance, some combination of:
        - Different queuing policies in router
        - Different security measures to handle threats
        - Different versions of the same protocols
        - ...

Experiment Principles

- Theory / Idea
  - Question: Is there a cause-effect relation
  - Goal: To answer the question
  - Hypothesis: The theorised result
- Observation (from study)
  - Vary treatment and observe outcome
- Validity threats to handle:
  1. Conclusion validity: Statistical relationship or significance
  2. Internal validity: Relationship is causal and there are no confounding factors
  3. Construct validity: Treatment and output reflects the constructs
  4. External validity: Can results be generalized outside scope of study?

Validity of Experiments (1/2)

- **Conclusion validity**
    - Treatment $\rightarrow$ outcome
    - Is there really a cause and effect relationship, or could it be chance (statistical significance)?
- **Internal validity**
    - Rule out uncontrollable or unmeasurable factors
    - Such as noise, uncontrolled variables or bias
    - Is there a factor that is not understood?

Validity of Experiments (2/2)

- Construct validity
  - Is the cause-effect relation in the theory, visible in your data?
  - Are treatments and measurements good matches to the theory constructs?
- External validity
  - Is cause-effect relation in theory, generalisable?
  - To what extent are conclusions valid in outside the study context?
  - e.g. another company or another domain

Validity: Example

- Theory / idea
  - Question: Is General Active Clause Coverage (GACC) as effective as Correlative Active Clause Coverage (CACC)?
  - Goal: Compare fault-finding effectiveness of the two criteria
  - Hypothesis: Fault-finding effectiveness differs between GACC and CACC
  - Hypothesis: Efficiency differs between GACC and CACC
- Observation (from study)
  - Generate a set of test suites with 100% coverage (GACC and CACC) for a set of programs
  - Run the GACC and CACC test suites against software mutants for the selected programs
  - Observe mutation score for each test suite and program – how many faults are detected by the tests?

Validity: Example

- Observation (from study): continued ...
  - Observe response times and the number of tests required
- Some validity threats to handle:
  1. Is the number of test suites, programs and faults sufficient?
  2. Is there any bias in selection of programs, faults and test cases?
  3. Are there any confounding factors, e.g., background processes or test suite ordering?
  4. Does a high mutation score imply effectiveness for real faults?
  5. Are the used programs representative for other software?

Threats to validity are discussed further in the lecture on ethics

Planning and Control is Crucial for all Experiments (1/2)

To trust results we need to trust all steps of the work

1. **Research question: What do we want to know?**
   - Can this question be answered by an experiment?
2. **Plan: How do we plan to answer this question?**
   - Can we control and observe necessary variables?
   - Will the interpretation correspond to reality?
3. **Hypothesis: How do we plan to test it?**
   - What is required to test the hypothesis?
   - What answer does the theory predict?

Planning and Control is Crucial for all Experiments (2/2)

4. Results: How do we plan so that we can trust the data?
   - How will we collect data?
   - Is there a risk for any bias or uncontrolled factors? If so, how to avoid or mitigate it?
5. Conclusions: Are the conclusions fully supported by the results?
6. Impact: Are the conclusions useful for anyone?

Careful experimental design is the key to success

Experimental Design

Experimental Design

- Scope
- Planning
- Operation
- Analysis and Interpretation
- Presentation and Packaging
    - The final lecture focuses on communicating research

Scoping → Derive Aim

- Analyse <Object>
- For the purpose of <Purpose>
- With respect to their <Quality Focus>
- From the point of view of <Perspective>
- In the context of <Context>

Part	Example
Object	Web server
Purpose	Evaluate
Quality focus	Effectiveness
Perspective	User
Context	Many Subject – 2 object

Possible Aim:
Evaluate the effectiveness of web servers X and Y from a user perspective.

Goal Definition Framework Example

Object	Purpose	Quality focus	Perspective	Context (Subject type – object type)
Product	Characterize	Effectiveness	Developer	1-1
Process	Monitor	Cost	Modifier	M-1
Model	Evaluate	Reliability	Maintainer	1-N
Metric	Predict	Maintainability	Project manager	M-N
Theory	Control	Portability	Corporate manager	
	Change		Customer	
			User	
			Researcher	

Planning

Planning

- Context selection (subjects, objects)
- Hypothesis formulation
- Variable selection
- Selection of subjects (if applicable)
- Choice of design type
- Instrumentation
- Validity evaluation (discussed earlier)

Context Selection

- Common dimensions
  - Off-line vs on-line
  - Student vs professional
  - Toy vs real problem
  - Specific vs general

Fair comparison e.g.:

- Same subject background
  - At group-level
- Same subject preparation
  - Except for what you test
- Same execution platform
  - Except for what you test

Hypothesis Formulation

Confirm theory

- Null hypothesis – Cannot separate effect of treatment from random noise ($i == j$)
- Alternative hypothesis – We can separate effect ($i \neq j$)
- Risk – Type-I-error
- Incorrect rejection of null – Type-II-error
- Incorrect non-rejection of null

Explore Relationship, ...

- Statement of expected result
- e.g. We expect:
  - Caching improves average throughput
  - Security decreases average throughput
  - Incorrect queuing policy increases jitter
  - OOP increases productivity

Variable Selection (1/2)

- Usually just one *dependent variable* (DV)
  - Derived directly from hypothesis
  - More than one increases risk of validity threats
    - Fishing and the error rate
- Assumption:
  - $DV = f(IV)$
- Input
  - Independent variables
  - Context
  - Factors – control variables
  - e.g. for fair comparison

Variable Selection

- Configuration
  - Combination of *intdependent variable* (IV) values
- Uncontrollable variables
  - e.g. cache content
  - e.g. background processes
- Statistics
  - Each configuration $\times$ number of trials
  - Mean value, standard deviation, best case, worst case, outliers, etc.
- Advice:
  - Vary one IV at a time – while keeping other IVs constant
  - Keep number of IV low (see table on next slide)

Variable	IV or DV	Treatment value
Av. throughput (packages/second)	DV	
# of clients	IV	1, 10, 100
Client access rate (Hz)	IV	1, 10, 100, 1000, 10000
Packet size (bytes)	IV	4, 32, 1024
Server cache size	IV	0, 1kB, 1MB
Network segments	IV	1, 10, 100
Context	e.g. common html p.	
Uncontrollable	e.g. cache replacement	

- Table gives 405 configurations!
- 30 trials gives 12,150 treatments!

Selection of Subjects

- Closely related to generalisation of results
  - Always ask: *"Is the sample representative of the population?"*
- Probability sampling
  - Probability of selecting each subject is known, e.g.:
  - Simple random sampling: random selection from list of population
  - Systematic sampling: start at random point, then select every nth individual
  - Stratified random sampling:
    1. Divide into groups with known distribution between them
    2. Apply random sampling within group

Selection of Subjects

- Non-probability sampling
  - Probability of selecting each subject is unknown, e.g.:
  - Convenience sampling (Can be realistic choice. Can be problematic.)
  - Quota sampling
- Size of sample matters
  - The larger the sample – the lower the error when generalising result
  - The larger the variability – the larger the sample needs to be
  - The larger the sample – the more expensive (time and/or money) is the analysis
- Advice: think sampling through before you start

Choice of Design Type

Proper design forms the basis for replication

Choice of design is closely related to the analysis

- The type of planned analysis might require certain design choices
- e.g. what statistical test to perform to reject the null hypothesis?
- How many trials are required?

General Design Principles

Randomization

- Applies to subjects, objects and order of tests
- Example: random selection among persons of a certain role at company and random assignment of treatment

Choice of Design Type

Blocking

- Eliminating undesired effects from a factor that we don't study
- Example: divide subjects into groups with different level of experience
- In case the effect of experience is not what you aim to study

Balancing

- Assign treatments so each has the same number of subjects
- Simplifies & strengthen analysis but is not necessary
- Example: the same number of persons in groups with and without previous experience

Some Standard Design Types

- In order of increasing complexity
    - One factor with two treatments
    - One factor with more than two treatments
    - Two factors with two treatments
    - More than two factors each with two treatments
    - ...
- Advice for final year project
    - Keep design simple
    - Aim is to do a well-designed and well-performed study
- The first 2 design types are discussed in the following slides
    - Further descriptions in Wohlin et al.

One Factor with Two Treatments

- Example: compare a new design method with an old
  - Factor = design method
  - Treatment = old & new
  - DV could be e.g. number of faults found

Subject	T1	T2
S1	X	
S2		X
S3		X
S4	X	
S5		X
S6	X	

Subject	T1	T2
S1	2	1
S2	1	2
S3	2	1
S4	2	1
S5	1	2
S6	1	2

One Factor with Two Treatments

- Example: compare a new design method with an old
- Design type:
  - Completely randomized
    - Same object for both treatments and random assignment of subjects
  - Paired comparison
    - Cannot be used if too much information is gained by 1st treatment
    - (Learning effect)
    - Random assignment of treatment order for subjects
    - Balanced if same number of subjects per treatment order

Subject	T1	T2
S1	X	
S2		X
S3		X
S4	X	
S5		X
S6	X	

Subject	T1	T2
S1	2	1
S2	1	2
S3	2	1
S4	2	1
S5	1	2
S6	1	2

One Factor, more than Two Treatments

- Example: investigate effect on SW quality from different languages
  - Factor = language, treatments e.g., Java, C++ and C, DV could be number of faults found
- Design type:
  - Completely randomized design
    - As uniform environment as possible, random assignment of subjects
  - Randomized complete blocked design
    - Random assignment of treatment order for subjects
    - Blocking is applied to mitigate effects from subject variability (divide into homogeneous groups)

Subject	T1	T2	T3
S1	X		
S2		X	
S3			X
S4	X		
S5		X	
S6			X

Subject	T1	T2	T3
S1	1	3	2
S2	3	1	2
S3	2	3	1
S4	2	1	3
S5	3	2	1
S6	1	2	3

Relation to Hypothesis and Hypothesis Test

Completely Randomized Design

- Possible hypothesis
  - $H0 : \mu_1 = \mu_2 = \ldots\ \mu_n$ where n is the number of subjects
  - $H1 : \mu_i \neq \mu_j$ for at least one pair of subjects (i, j)
- Examples of tests
  - ANOVA (ANalysis Of VAriance) and Kruskal-Wallis

Subject	T1	T2	T3
S1	X		
S2		X	
S3			X
S4	X		
S5		X	
S6			X

Subject	T1	T2	T3
S1	1	3	2
S2	3	1	2
S3	2	3	1
S4	2	1	3
S5	3	2	1
S6	1	2	3

Relation to Hypothesis and Hypothesis Test (2/2)

Randomized Complete Blocked Design

- Possible hypothesis
  - $H0 : \mu_1 = \mu_2 = \ldots\ \mu_n$ where n is the number of subjects
  - $H1 : \mu_i \neq \mu_j$ for at least one pair of subjects (i, j)
- Examples of tests
  - ANOVA (ANalysis Of VAriance) and Kruskal-Wallis
- Advice for final year project
  - Keep it simple
  - Analysis and hypothesis testing is required

Subject	T1	T2	T3
S1	X		
S2		X	
S3			X
S4	X		
S5		X	
S6			X

Subject	T1	T2	T3
S1	1	3	2
S2	3	1	2
S3	2	3	1
S4	2	1	3
S5	3	2	1
S6	1	2	3

Instrumentation (1/2)

Instruments are:

- Objects, e.g.
  - A specification
  - A code
  - An interface
  - …
- Guidelines needed to guide participants (subjects), e.g.
  - Process descriptions
  - Checklists
  - …

Instrumentation

- Training might also be necessary in some cases
    - Measurement instruments, e.g.
    - Forms for data collection if collected by participants
    - Tools for data collection if collected by machine
    - What to measure, how to measure and how to classify collected data?

Operation

Preparation

- The better the preparation – the easier the execution
- Select and inform participants
  - Subjects need to be motivated
    - If not serious – results are invalid
  - Consent
  - Right to withdraw (can be complex to manage)
  - Sensitive results
    - How can subjects be kept anonymous?
  - Full disclosure
- Prepare materials, e.g., tools, forms, etc.

Operation

Execution and Data Collection

- Level of control: One well-monitored occasion or spread over time
- Data collection: manual, tool-supported or automatically by tools

Data Validation

- Check that data is reasonable, correctly collected and classified
- Identify sources of errors (false data points)
- e.g. treatment applied in wrong order $\rightarrow$ data is invalid
- Check outliers and decide whether the data point is an error or not

Analysis and Interpretation

Descriptive Statistics

- Describing interesting aspects of the data, e.g.
- Mean value, median value, distribution ...
- Visualisation by graphs, diagrams, box-plots, scatter plots ...

Data Set Reduction

- Remove invalid data
- Analyse outliers to decide whether to include or remove
- Decision should be based on whether the data is valid and provides useful information
- Redundant data can sometimes be removed
- Be careful –- use a recommended analysis technique

Hypothesis Testing

- Objective to see whether the null hypothesis can be rejected
- If the null hypothesis is rejected
  - It is false with a given statistical significance (α)
- There are a lot of statistical tests
  - Most common statistical tests described in Wohlin et al.
- Choice of statistical test depends on the hypothesis and data set
  - Is the data normally distributed? Use a test to check.
  - What value of α should be used?
  - Discuss with supervisor if in doubt

Final Year Project Advice

Keep things simple!

Final Year Thesis Advice

- Keep things *simple*!!!
  - Your goal is to show that you fulfill the learning goals, e.g.:
    - Formulate and motivate a research question
    - Make a well-motivated choice of research method
    - Apply the method in a good way (i.e. design, plan, execute and analyse)
    - Each choice and step is clearly motivated and described
  - So much easier to do with a small, well-defined study
- Hypothesis testing is required
  - Choose a test that fits your study in order to show significance
  - It gives more weight to your work and arguments for your conclusions
- But don't forget, there are so many more things you can do to analyse your data
  - Visualise the interesting aspects
  - This will support your conclusions

IT513G: Research and Development

F7: Research Ethics

Validity Threats and Societal Impact

IT513G: Research and Development

F7: Research Ethics

Validity Threats and Societal Impact

University of Skövde

Overview

Research Ethics

Research Quality and Reliability

Ethics and Authorship

Digitalisation for Sustainability

Final Year Project Advice

Research Ethics

Ethics is not a Modern Invention

A definition of ethics: **Norms for conduct that distinguish between acceptable and unacceptable behavior**

- Ethics has been discussed for a very long time
  - e.g. Hippocratic oath around 2500 years ago
  - Aristotle's *Nicomachaen Ethics* around 2200 years ago
  - Nash-papyrus with the ten commandments around 2200 years ago
- Ethics might even be older than the human species
  - Given the chance to get food by pulling a chain that would also deliver an electric shock to a companion, rhesus monkeys will starve themselves for several days
  - There are reported observations of ethical behavior in other animals too

Ethics

- As the world changes new ethical dilemmas are identified and standpoints developed
  - Such as digitalization and the use of AI and IoT
  - Often related to aspects such as:
    - Privacy or integrity;
    - Impact on human intellect and productivity; and
    - Energy and resource consumption, and carbon emissions.
- Professional bodies often have a code of ethics
  - e.g. ACM `https://www.acm.org/code-of-ethics`

Morals, Ethics and Law

- Everyone has a set of morals that defines their behaviour
  - Not necessarily reflected on or consistent
  - Through my choices and actions I show what my morals are
- Ethics is something we are aware of – we reflect on ethics
  - A theory of morals – formulated norms
  - Justifying our position - allowing us to work together and form a system
- Both morals and ethics contain normative assumptions
  - What is good or bad

Morals, Ethics and Law (2/2)

- **Research ethics** are norms that the research community has reflected on, formulated and motivated
- Legislation is also used to support the field of research ethics
  - With respect to certain principles regarding e.g. studies involving animals or humans
  - With respect to misconduct (oredlighet)
- Laws are national, but ethics and morals are cultural and cross borders
- Today's focus is on research ethics

Why Research?

- Basic research
  - Develop new knowledge – a value of its own
  - May or may not lead to valuable consequences
  - People need to make sense of the world
- Applied research
  - Develop new knowledge in a specific area
  - Goal to improve treatments, products, processes ...
- Other values
  - Critical thinking, quality of life, revitalized public debate ...
- There are also risks, e.g.
  - A new, effective medicine with serious side-effects
  - A tool to automate security improvement that could be used for cyber attacks

Misconduct

- Fabrication of data
- Theft or plagiarism
  - e.g. hypotheses or methods from other researcher's application or publication without giving the source
- Distortion of the research process in other ways
  - e.g. wrong use of method, dishonest inclusion or exclusion of data, fraudulent analysis of data to distort its interpretation

Misconduct is not just a question of cheating. All research is about building knowledge based on what we already know. In a worst case scenario a false result can cause hundreds of researchers around the globe to waste many years and billions of funding on a wild goose chase because of the false assumptions they started out with.

Six Domains of Ethics (1/6)

- **Scientific integrity** – the relationship between research and the truth
- **Collegiality** – relationships between researchers
- **Protection of human subjects** – relationships between researchers and human subjects
- **Animal welfare** – relationships between researchers and animal subjects
- **Institutional integrity** – relationships between researchers, their sponsoring institutions, funding agencies, and the government
- **Social responsibility** – relationship between research and the common good

Six Domains of Ethics

- **Scientific integrity** – the relationship between research and the truth
  - Basic technical competence
  - Statistical methods
  - Falsification
  - Fabrication and unintentional bias
- **Collegiality** – relationships between researchers
  - Authorship
  - Data sharing and timely publishing
  - Plagiarism
  - Peer review
  - Confidentiality
  - Candour
  - Mentorship

Six Domains of Ethics

- **Protection of human subjects** – relationships between researchers and human subjects
  - Belmont report (Ethical principles and Guidelines for the Protection of Human Subjects of Research) including Access to treatments
  - Protection from harms: respect for persons (autonomy); beneficence (plus non-maleficence); justice
  - Informed consent
  - Assent
  - Confidentiality and anonomity
  - Deceit
  - Debriefing
  - Research risks and benefit

Six Domains of Ethics

- **Animal welfare** – relationships between researchers and animal subjects
  - The 3 R's (replacement, reduction and refinement)
  - Pain and suffering
  - Enrichment
  - Animal rights

Six Domains of Ethics

- **Institutional integrity** – relationships between researchers, their sponsoring institutions, funding agencies, and the government
  - Conflict of interest
  - Conflict of commitment
  - Regulatory compliance
  - Data retention
  - Institutional oversight
  - Institutional demands and support

Six Domains of Ethics

- **Social responsibility** – relationship between research and the common good
  - Research priorities
  - Fiscal responsibility
  - Public service
  - Public education
  - Advocacy by researchers
  - Environmental impact
  - Forbidden knowledge

The Uppsala Code

- Appeals to researchers to avoid research that:
  - Lead to ecological harm
  - Development of weapons
  - Is in conflict with basic human rights
- Intended to be used to evaluate own research (or colleagues')
- Encouraging researchers to
  - Not participate
  - Make their opinion publicly known
- At the same time – loyalty is crucial
  - Colleagues depend on the researcher's work
  - Seldom necessary to leave in the middle of a project
  - Better to jump off between projects if possible

Ethics in Tech and Natural Science

- Research should only be approved if it can be conducted with respect for the human value. Human rights and fundamental freedoms should always be considered during ethical trial
- Human wellbeing should be prioritized over societal and scientific need
- The ethical considerations in software engineering are however mostly about the consequences of research
  - While research involving humans often concerns integrity and autonomy
  - Example: AI can give advantages, but long-term consequences are unclear

Ethics in Studies Involving Humans

- Informed consent to participation
  - Subjects must be fully informed before deciding to participate
  - Decision must be explicit and free
- Scientific value of study
  - Even if risks are minimal, subjects are not exposed to risks unless there is a scientific value motivating the subjects
- Confidentiality of data and sensitive information
  - Data privacy, data anonymity and anonymity of participation
  - Individual performance, conclusions when a sponsor has a stake, failing hypothesis…
- Weighing risks, harms and benefits, the benefits must be greater
  - For the subjects, but also for the group of subjects and organisations
- Sometimes an *ethical review* is required before the study is permitted

Handling Research Material (1/2)

- There's a built-in tension between:
  - Requirements on public access, openness and transparency vs.
  - Requirements on protection of subjects' and informants' personal integrity
- Openness and transparency is necessary for re-use of research
  - Collected data is not a private property — it must be archived
  - Research data should be FAIR (**F**indable, **A**ccessible, **I**nteroperable and **R**eusable)
  - `https://snd.gu.se/sv/beskriv-och-dela-data/vad-innebar-fair-data`

Handling Research Material (2/2)

- Four important concepts
  - **Secrecy**: only if addressed in the Official Secrets Act (sekretess)
  - **Professional secrecy**: in certain professions (tystnadsplikt)
  - **Anonymizing/de-anonymizing**: eliminating connections between data and individuals
  - **Confidentiality**: protection from unauthorized access
- Researchers cannot promise to keep data secret
  - What if someone wants to continue the work?
  - What if someone suspects misconduct?
- At the University of Skövde support is provided to researchers by the Data Access Unit (DAU)
  - `https://www.his.se/mot-hogskolan/sa-har-fungerar-hogskolan/organisation/namnder-rad-och-andra-organ/data-access-unit/`

And Then There is the Question of Honesty ...

- Guns in the home found to increase risk of death
  - Study showed: People who keep guns at home nearly triple their chances of being murdered, usually by friends or relatives, but fail to protect themselves from intruders
  - The article describes how the study was conducted, summarizes aspects of the population cross sections and conclusions of the study, and concludes with a refutation by a representative of the National Rifle Association (NRA)
- Paul Blackman, research coordinator at the NRA, criticized the study
  - “These people were highly susceptible to homicide”, he said.
  - “We know that because they were killed”

… and reliability

- Japanese people eat very little fat and suffer fewer heart attacks than British or Americans
  - Conclusion: Eat little fat and live longer
- On the other hand, French people eat a lot of fat and also suffer fewer heart attacks than British or Americans
  - Conclusion: Eat what you like – speaking English will kill you
- Be careful who you fool "The first principle is that you must not fool yourself – and you are the easiest person to fool" Richard Feynman (Nobel Physics, 1965)
- Both the honesty and the reliability examples relate to the ethical domain of scientific integrity

Research Quality and Reliability

Research Quality and Reliability: General Principles

- A project should:
  - Have a clear aim to answer or highlight specific questions
  - Preferably be creative and innovative
- Method should be:
  - Possible to explain
  - Possible to show that using the methods should allow the researcher to answer the questions
  - Handled correctly and competently
- Projects based on empirical studies should be characterized by:
  - Careful collection of data
  - Systematic and critical analysis of the data
- Sources of errors should be identified and discussed
- Report should exhibit clarity, order and structure

Principles of Experimentation

- Theory / idea
  - Question: Is there a cause-effect relation
  - Goal: To answer the question
  - Hypothesis: The result we expect
- Observation (from study: vary treatment and observe outcome)
- Validity threats to handle:
  1. Conclusion validity
     - Statistical relationship / significance
  2. Internal validity
     - It's causal and no other factor disturbs
  3. Construct validity
     - Treatment and output reflects the constructs
  4. External validity
     - Can results be generalized outside the scope of the study

Evaluation of Validity

- To what extent are the conclusions supported by the results?
  - This question should be asked for each conclusion
  - A matter of **conclusion validity**
- To what extent can we trust the results of our study?
  - This question should be asked *before* and *during* study design
  - Long before data collection and analysis is conducted
  - What data to collect and how to collect it is part of study design
  - Matters of **internal** and **construct validity**
- To what extent do the results apply to a broader population?
  - This question affects the contribution and should be considered early
  - A matter of **external validity**

Conclusion Validity

- Concerned with the relationship between treatment and outcome
- Is it a statistical relationship?
  - With a given significance?
- Or is it just an observation?
  - A black cat crossed the street and I lost my wallet
  - Makes sense if you believe in such things
  - But it is just one observation – no statistical relationship
- Concerns issues that affect the ability to draw correct conclusions
  - Between the treatment and the outcome

Conclusion Validity Threats: Examples

- A few examples:
  - Sample size
    - “Vast majority, 67%, agrees with ...” when only 3 subjects were asked
  - Response rate
    - “90% agrees with ...” when in fact only 10% answered the questionnaire
  - Ignoring significance
    - ”A is much more efficient than B” when in fact the difference is marginal
  - Bias
    - 100% agree or agree strongly with statements in survey, when those were the only rational responses to the survey

Internal Validity

- Concerned with factors we do not control because we:
  - Cannot control them
  - Are unaware of them
  - Don't think they matter
- We want to know whether the relationship is causal
  - i.e., whether it's the treatment that causes the effect
- Hence, ambiguities and other factors affecting the outcome must
  - Be identified
  - Be handled
- Level of control that can be achieved differs
  - But must always be accounted for

Internal Validity Threats: Examples (1/2)

- “90% agree that A is better than B” when:
  - 90% belongs to a certain group that are more familiar with A
  - A was promoted by the study leader
    - Better described
    - Clearly preferred when presented
    - Subjects where somehow rewarded by preferring A
- “A is much faster than B” when:
  - The load was not the same when they were executed
  - No control of background processes
  - The platform / execution environment was not the same
  - Execution time is just a small part of the measured time span
  - e.g. 90% spent on I/O and the difference depends on which part of memory that was used

Internal Validity Threats: Examples (2/2)

- "Higher program complexity causes higher error rate"
  - We can see a correlation but is it a causal effect?
  - Maybe it's the complexity of the problem that causes both

Construct Validity

- Concerned with how well the experiment reflects what we want to study
  - Choice of treatment or independent variables
  - To what extent do they reflect the cause construct?
  - Choice of measurements, i.e., dependent variables
  - To what extent do they reflect the effect construct?
- It's quite common that the thing we want to measure cannot easily be interpreted as a measurable output
  - e.g. what is the effect on performance? How to measure?
    - Define the specific aspects of performance that you are interested in and then
    - Choose metrics that are directly related to these aspects,

If the constructs are not clearly defined the study cannot be clear

Construct Validity Threats: Examples

- Coverage criteria and fault-finding capacity
  - The author developed criterion A and the faults to find in experiment
  - Knowledge or expectation might affect the choice of faults
- Usability comparison of tools
  - Learning effects: all subjects first tried tool A and then tool B
- Comparing methods' effect on productivity
  - Without considering any negative effects on e.g., maintenance
- Exploring preferences or attitudes among people
  - The researcher has his/her mind set from the beginning
  - The subjects can clearly see the expectations
- Exploring consumption changes in a population
  - "Consumption of sweets has increased during the last five years"
  - Measured money spent on sweets and the prices had increased

External Validity

- Concerns the ability to generalize the results to industrial practice
- The set of subjects has to be representative w.r.t. the population we want to generalize to
- The setting and materials have to be representative w.r.t. the setting we want to generalize to
- The history has to be accounted for since recent events can affect the result

External Validity Threats: Examples

- Study on code inspection conducted with programmers only
  - While we want to generalise to all involved – programmers, testers and system engineers
- Study conducted on toy examples
  - While we want to generalize to large industrial systems
- Study conducted with old tools
  - While we want to generalize to an industry that no longer use these tools
- Questionnaire on privacy
  - Sent out just when serious privacy issues are revealed and covered by media

Ethics and Authorship

Illustration of an Ethical Issue in Computing Research

Authorship and Ethics (1/2)

Vancouver Rules The Vancouver Rules consist of four criteria for scientific authorship. All four criteria must be met in order for someone to be considered as an author of the publication.

- Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
- Drafting the work or revising it critically for important intellectual content; AND
- Final approval of the version to be published; AND
- Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

The HiS Guidelines on Scientific authorship include the Vancouver Rules

Authorship and Ethics (2/2)

Generative AI

> *"The use of generative AI tools and technologies to create content is permitted but must be fully disclosed in the Work."*
> *Association for Computing Machinery (ACM) Policy on Authorship*

https://www.acm.org/publications/policies/new-acm-policy-on-authorship

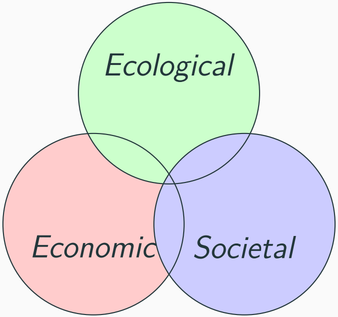
Generativ AI, t.ex. ChatGPT

Att skapa en text med hjälp av ChatGPT för att ge intryck av att det är en själv som skapat texten kan ses som ett försök till vilseledande (fusk).

Kammarrätten i Göteborg, mål nr 7132-23

Digitalisation for Sustainability

Digitalisation for Sustainable Development



- Theme for the University of Skövde
- Based on UN's Agenda 2030 and its 17 sustainability goals
- Ongoing work to explore possibilities and risks with digitalisation when developing a sustainable society

In Software Development

- Directly, for example:
  - Execution time comes with an environmental cost
  - Time for development and maintenance is usually the major factor influencing the environmental cost
  - Reduced development time and increased execution time for an application might therefore reduce the total environmental cost
  - Can we reduce the need for maintenance by e.g. continuous deployment?
- But it's also a question of **what** we develop
  - Can the software we develop help build a more sustainable world?

Digitalization for Sustainability

- Digitalization is an important factor when it comes to building a sustainable society.
- It can for example:
  - Help us develop solutions to provide care for an increasing number of elderly people
  - Provide digital solutions to reduce negative effects on the environment
    - e.g. by intelligent transportation systems
  - Promote cultural diversity
    - e.g. by digital distribution of culture
  - Develop our democracy by increasing dialogue with decision makers
  - Increase our society's competitiveness by developing new digital products, services and business models

Final Year Project Advice

What to Think of When Writing Your Final Year Report? (1/2)

- Your thesis includes two discussion sections:
  - Method / approach description
    - Subsection describing how the method is applied in an ethical way in your study
  - Post mortem analysis of ethics and societal impact
    - Including a discussion related to sustainable development
- What to discuss?
  - Result and method
    - Strengths and weaknesses
    - Threats to validity, how you handled them and what remain unhandled
  - Effects of your work apart from the obvious
  - Ethical and societal considerations and effects

What to Think of When Writing Your Final Year Report? (2/2)

- Select the validity threats and ethical issues that are the most relevant
  - i.e. that might apply to your own study
- Then describe what you have done to handle each of them
  - Some might been avoided, some mitigated and some remain unhandled
- It's all about scientific rigour and honesty
  - Do the best possible and be **open** with the remaining threats and limitations
  - **This way others can judge to what extent and within which limitations the results can be trusted**
- If you want to learn more: "God forskningssed" by Vetenskapsrådet
- `https://www.vr.se/analys/rapporter/vara-rapporter/2017-08-29-god-forskningssed.html`

Items to Discuss in Thesis

- Are results and measurements published?
- Are source code and data public?
- Can the study easily be replicated?
- Are human test subjects well protected?
- Do you violate patents or copyrights?
- Can your result harm or benefit the surrounding society, e.g.
  - Can it save energy or time?
  - Is there a risk of spreading virus?
  - Is there a risk of spying on users?
  - Can your result harm users physically or economically?
  - Can the society learn something from your result?
  - How can your contribution impact sustainability?
    - In an ecological, societal and/or economic perspective

HiS: Ethics committe and good research practice

- https://www.his.se/mot-hogskolan/sa-har-fungerar-hogskolan/organisation/namnder-rad-och-andra-organ/forskningsetiska-radet/god-forskningssed/
- https://www.his.se/mot-hogskolan/sa-har-fungerar-hogskolan/organisation/namnder-rad-och-andra-organ/forskningsetiska-radet/

IT513G: Research and Development

F8: Communicating Research

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University of Skövde

Overview

Target Audience

Narrative

Visualisation

Language and Style

Target Audience

“Knowledge is an unending adventure at the edge of uncertainty.”

Jacob Bronowski

Be mindful of your audience

- **Who are they?**
- **What do they know?**
  - **Presentations** – the audience should be relatively predictable
  - **Thesis** – more difficult.
    - Examiner(s) and supervisor
    - Who else? Academics? Other students in similar area?
- **The golden rule: Do not waste the audience's time**
  - "Listening to and reading things I don't understand is annoying"
  - "If I cannot follow you I get nothing out of attending or reading"
  - "Listening only to things I already know is boring"
  - "If I don't learn anything I get nothing out of attending or reading"

Target Audience

- However, the audience will have a variety of knowledge & understanding, so you need to find a balance
- **What can you expect everyone to know?**
  - Briefly provide some context to make them feel comfortable
- **What can you expect that part of the audience does not know?**
  - Describe and explain in enough detail so that the vast majority can understand what you've done and why
- **What can you expect none of them to know?**
  - This is what you need to focus on
- In the core of a presentation *expect to lose some of the audience*
  - But they need to understand the problem and motivation and end (tie back)
- **In the report you shouldn't lose any reader**

Narrative

Narrative: Outlining Your Report

- Outline of report sections is quite straightforward
  - Introduction, background, problem, method, results, discussion, conclusion
  - With some variation depending on subject and personal preferences
- For each section there's a message and a story
  - You need to know **what** you want to say before deciding **how** to say it
  - What is your story?
  - What is your main message?
  - What does the reader need to know before you deliver this message?
- Answers to these questions helps to identify the need for subsections
  - So you get a first outline of the section
  - You can do the same for paragraphs in subsections
  - *Each paragraph* carries a message to the reader

Narrative: Creating a Flow (1/2)

- Some sections can only be outlined at a high level to begin with
  - e.g. results and discussion
- Work iteratively with placeholders, e.g.
  - `--- --- Describe x here --- ---`
  - `--- --- Motivate y here --- ---`
- If a section or paragraph doesn't fit into the story then:
  - Move or remove it for now
  - But *save the text* in case you find a place for it later
- Improve the flow by connecting sentences and paragraphs
  - Final sentence of a paragraph should **ideally** convey a message picked up by the next paragraph in the same section
  - Final paragraph of a section should **ideally** convey a message for the section picked up by next section

Narrative: Creating a Flow (2/2)

Ideas have a lifespan in the paper or presentation

- Some may belong to a section, or subsection (or slide)
- Others may, for example, be present in the Introduction and the Discussion
- Example arcs:
  - Motivating example(s): Introduction, Discussion (& Conclusion ?)
  - Research Questions: Introduction, Method, Results, Discussion, ...
  - Important related works: Introduction, Background, Method, Discussion, ...

Checkov's Gun

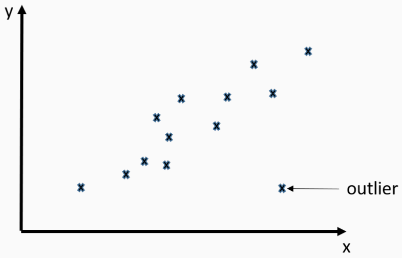
- A notion of efficiency and purpose in writing.
- If you mention something, it *must* be relevant; and be used!
- e.g. James Bond gets *n* new weapons and gadgets before each mission; all are relevant to the story and used to solve problems before the film ends

Visualisation

Visualisation of Results

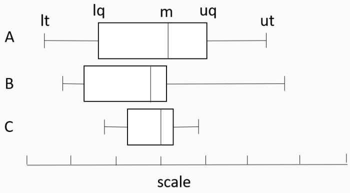
- Results are usually collected as raw data in a first step
  - Might be published somewhere (appendix or website), not in the report
  - You need to help the reader to see the patterns
- You should make the results:
  - Interesting and understandable for the reader
- First step is to analyse the data
  - Visualise the aspects that are interesting from the perspective of
  - Problem, research questions, hypotheses
  - Such aspects are often e.g.,
  - Distributions, trends, relations, correlations, limits, categories...
- Then present the results while pointing to the visualization
  - Tables, graphs, etc.
  - Ideally the readers will agree with everything you say while reading

Visualisation Example: Scatter Plots



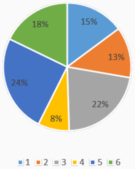
- Pairwise samples (x_i, y_i)
- Shows distribution
  - Spread or tight
  - Linear relations
  - The figure shows a positive correlation between x and y
  - Outliers – one identified in figure
- Good to identify dependencies
  - In this case between x and y
- Note that this doesn't imply cause-effect

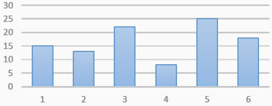
Visualisation Example: Box Plots

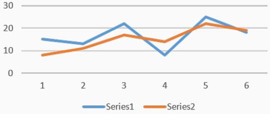


- There are variants. An example:
  - lt: lowest value
  - ut: highest value
  - m: median
  - lq is the median of the 50% lowest values (lt to m)
  - uq is the median of the 50% highest values (m to ut)
- Shows dispersion and skewedness
- Lots to discuss in figure, e.g.
  - B has highest "best" case but lowest median
  - A has highest median but lowest "worst" case
  - C did not score as high as A or B but was more predictable

Other Visualisation Examples







Pie chart: show proportions of a whole

Histogram: compare across categories

Line chart: compare trends over time

Visualisation: Things to Consider

Clarity

- Label axes carefully: are the units stated? and is the font is readable?
- Use the conventional or expected type of visualisation for the data.
- Be kind to the reader or the audience.

Colour

- Choose colours with care:
  - Accessibility guidelines will help select suitable colours and contrast
  - Remember that some people assign semantics to colour, which can cause confusion, e.g.

DISKAD ODISKAD

Language and Style

Language and Style

You are writing a **technical report in academic-style language**

- Don't be creative with concepts
- Decide which concepts to use, define them and then use them consistently throughout the text
- Each sentence should say one thing
- Each paragraph should deliver one message
- ~~Avoid~~ Do not use slang expressions
- Spell words out (i.e. don't use apostrophes for contractions)
  - e.g. write "it is" instead of "it's"
- Do not use words and phrases commonly used by ChatGPT and other GenAI tools
  - e.g. "delve", "dig into", "dive into", "crucial", ...

Language and Style (2/2)

- Don't write about yourself or your personal experience
  - Keep an objective view throughout the report
  - State facts with references
  - Describe your approach thoroughly and objectively
  - Report on results objectively
  - Only in the discussion section is room for speculation, but be clear
  - e.g. "... one possibility is ..." or "... one interpretation could be ..."

Use Spelling and Grammar Checkers

Use tools to check the text. Spellcheckers are built in to editors and grammar checkers are available.

If you use *distraction free* editors when writing, or turn the spellcheckers off, remember to use the tools later in your workflow.

Never hand in a text that has not been checked for grammar and spelling mistakes.

Presentation: Anatomy of a Good Talk (1/2)

- Beginning and introduction
  - Connect your work to something the audience already knows or understands
  - Motivate your work
  - Define the research problem
  - Explain why it is interesting, important and exciting
  - Explain its context: How does it differ from other research
- Present new material in increasing levels of difficulty
  - Explain what you did
  - Don't be comprehensive — convey the big picture
  - Use pictures, 1–2 examples, etc.

Presentation: Anatomy of a Good Talk (2/2)

- Analysis
  - Did your work solve the problem?
  - What are the important broad implications of your work?
- Summarise your project with one or two key points
  - If your audience remembers one thing from your talk, you have succeeded
  - If they remember two things, you're doing really well
- End by relating your talk to something the audience knew before they came — something familiar
  - For example, it might be a point used in the introduction to link the audience's knowledge to the subject.

Presentation: Do's and Don'ts (1/3)

- Don't read slides
- Point at screen
  - Don't point at your computer
  - Light pens take practice to handle
  - Pympress and PowerPoint include emulated laser pointers etc
- Anticipate questions
  - Think of the 10 most difficult or embarrassing questions and practice on their answers
  - Answer questions clearly
- Pick out people
  - 4–5 equally distributed in the room and talk directly to them now and then
  - Look directly at someone when making an important point

Presentation: Do's and Don'ts (2/3)

- Stand up
  - Even if it's a small audience
  - Sitting down makes your voice drop and your focus is drawn to the computer instead of the audience
- Speak clearly and assertively
  - Even when you answer "I don't know"
  - Don't use words you don't understand
  - Don't let your voice drop when you're less confident
- Introduce yourself and your topic
  - The audience spends the first 20–30 seconds getting used to your voice
  - Be careful not to say anything too important in the first 10-20 seconds

Presentation: Do's and Don'ts (3/3)

- Don't fidget
  - Be fairly still and try to look comfortable
  - Don't check your watch or wring your hands
  - Looking nervous makes people look harder for flaws
- Be (very) careful with humour — it often backfires
- Be aware of what you are wearing
  - Religious symbols may cause offence
  - Messages on clothing can be distracting

Presentation: Advice

- Average **2 minutes per slide**
  - Time your presentation!
- Think carefully about the audience and what they know
- Use pictures
- Use colours with care
- Put at most five major bullet points on your slides
  - People should be able to read slides quickly — and then listen to you
  - **NB** classroom slides are used for reference, so they are not good examples

– Use `consistent` styling and fo*nts on sli*des

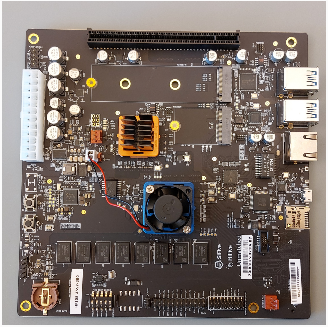
* Unexpected **changes in** *style* are DISTRACting **!!**

- But, **careful** use of **typography** can **support** the **message**

Presentation: Advice

Illustrations — graphs, photographs, diagrams — can be a powerful way to help **communicate complex ideas** as well as results

Illustrations should be clear and support what you are saying, and allow you to talk about the content. e.g.



RISC-V development board above supports around 5 minutes talk.

But, all images must be relevant to the research and the presentation

Irrelevant images are distracting

Presentation: Advice (2/2)

Practice!

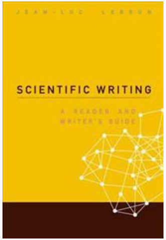
- Without an audience:
  - Maybe in front of a mirror
  - Maybe use an audio recorder – good for timing, and can use Whisper to transcribe
  - In front of your project group members
  - In front of friends not familiar with your project

Rehearsing your presentation

- Helps you remember the talk
- Makes delivery more confident
- Helps you to find errors and flaws

Two Useful Books

Understanding Comics
Scott McCloud
Two copies in the library



Scientific Writing: A Reader and Writer's Guide
Jean-Luc Lebrun
Two editions
Full text available online through the library