SCIENTIFIC RESEARCH METHODOLOGIES AND TECHNIQUES

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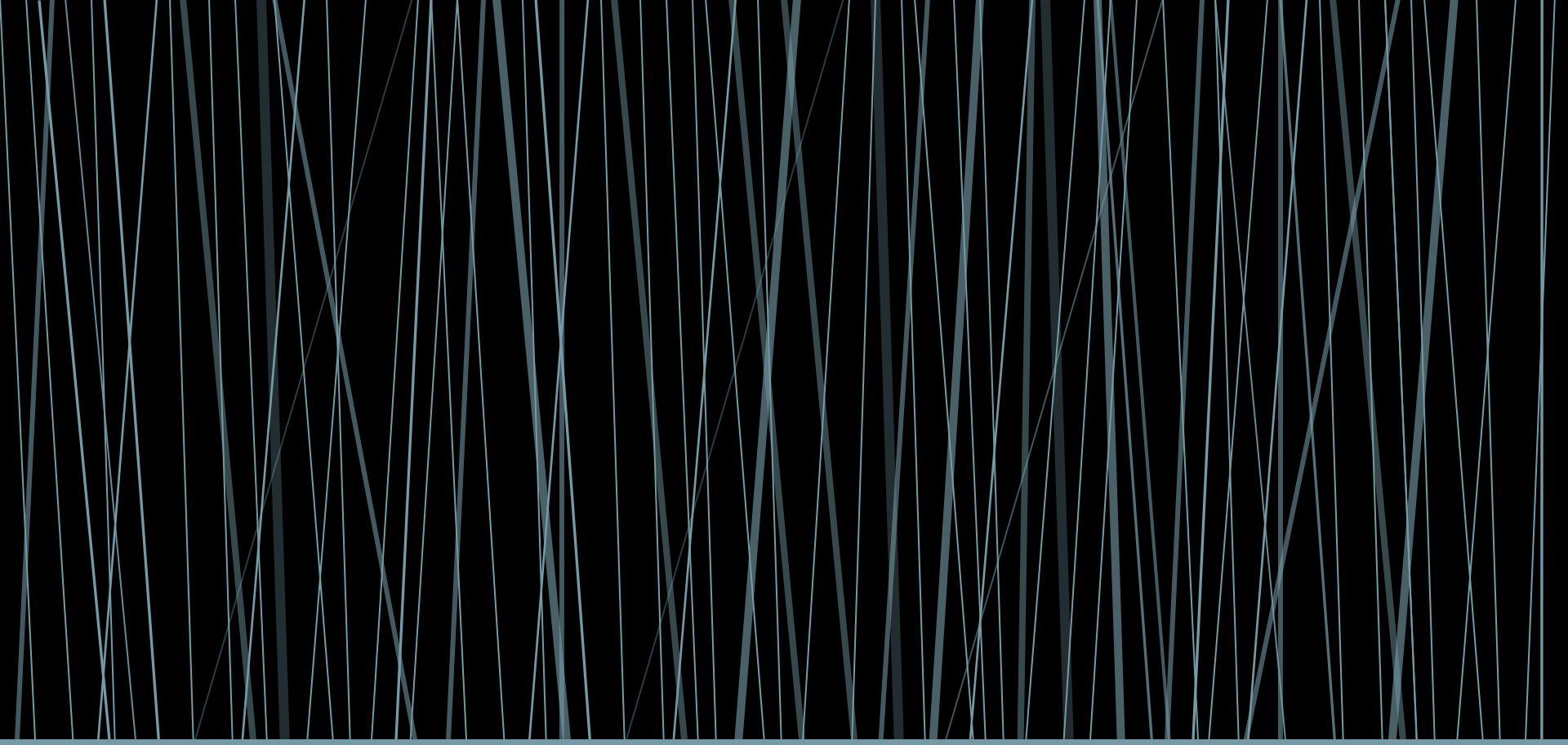


Base Terminology

TERMS

Methodology - the **study of the methods** involved in some field, endeavor, or in problem solving

Method - a (systematic ?) codified **series of steps** taken to complete a certain task or to reach a certain objective

Methodology is defined as:

- "the analysis of the principles of methods, rules, and postulates employed by a discipline";
- "the systematic study of methods that are, can be, or have been applied within a discipline"; or
- "a particular procedure or set of procedures."

- a collection of theories, concepts or ideas
- comparative study of different approaches
- critique of the individual methods

Methodology refers to more than a simple set of methods;
it refers to the rationale and the philosophical assumptions that underlie a particular study.

In recent years *methodology* has been increasingly used as a pretentious substitute for *method* in scientific and technical contexts [Wikipedia]

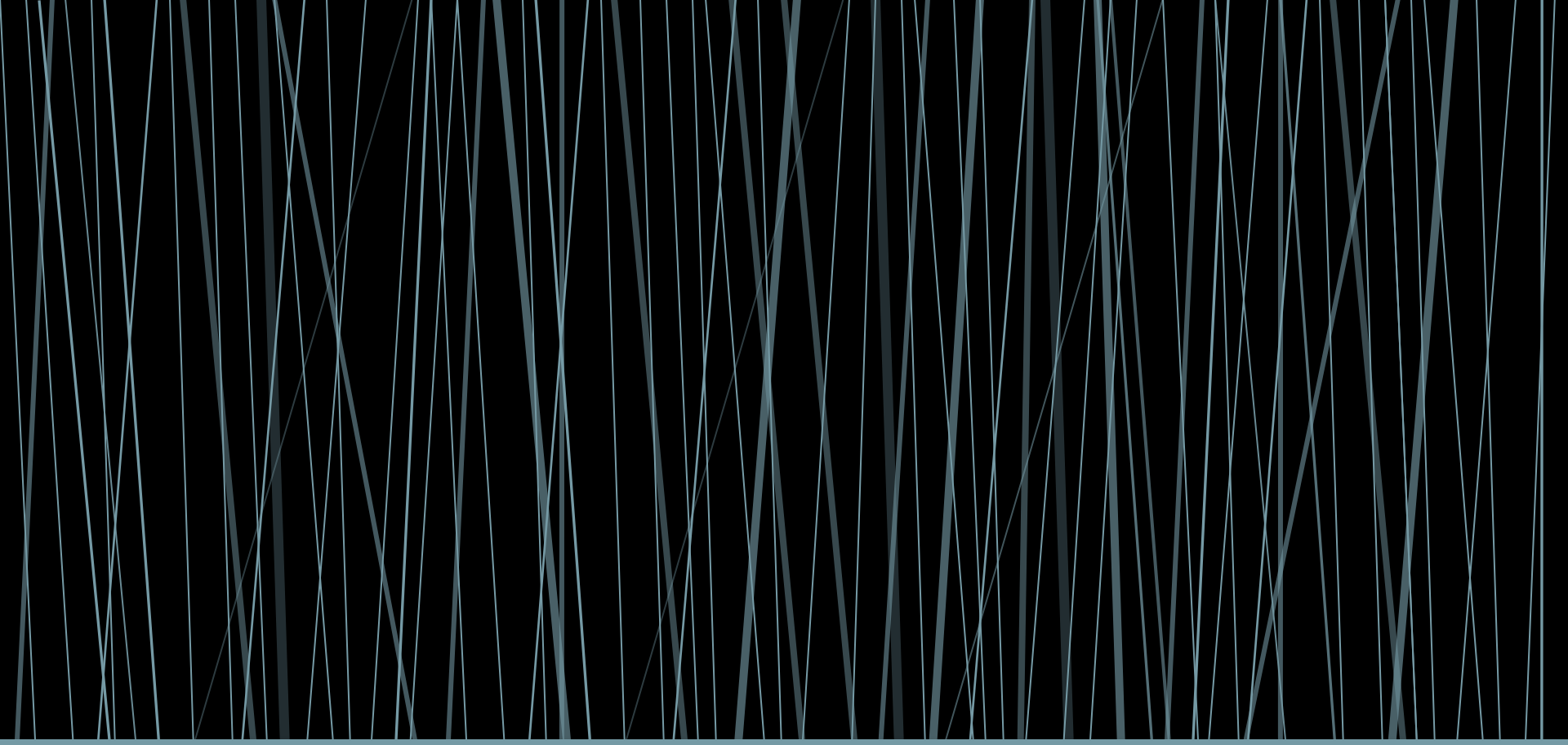
Natures of Scientific Method

The "scientific method" attempts to minimize the influence of the researchers' bias on the outcome of an experiment.

- ***The researcher may have a preference for one outcome or another, and it is important that this preference not bias the results or their interpretation.***
- ***Sometimes "common sense" and "logic" tempt us into believing that no test is needed.***
- ***Another common mistake is to ignore or rule out data which do not support the hypothesis.***

http://teacher.pas.rochester.edu/phy_labs/appendixe/appendixe.html

But there is no single, universal formal "scientific method". There are several variants and each researcher needs to tune the process to the nature of the problem and his / her working methods.



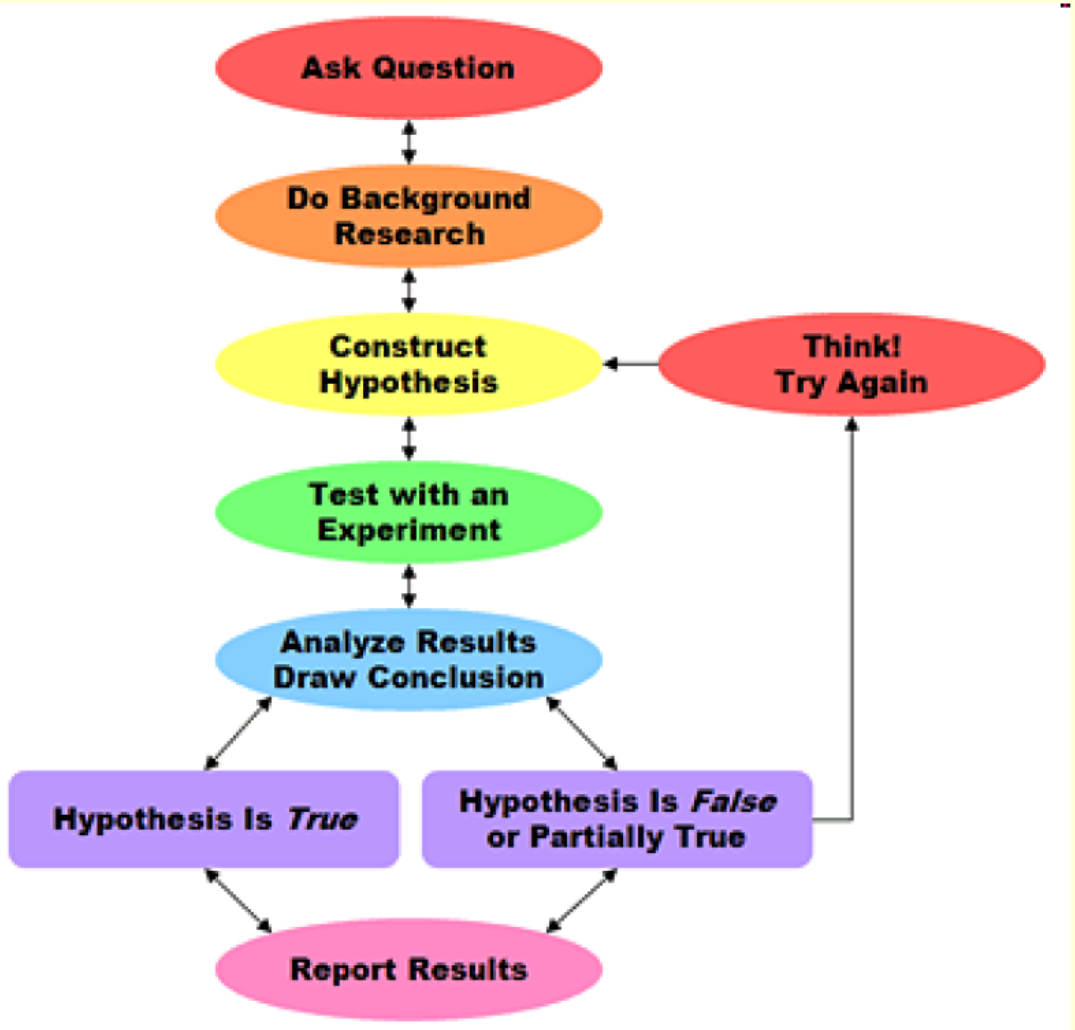
Overview of Research Method

Classical Methods

Classical Methods

1	• **Research question / Problem**	What are you interested in? What do you have to know about it?
2	• **Background / Observation**	Make observations & gather background information about the problem.
3	• **Formulate hypothesis**	An *educated guess* … It shall be possible to measure / test it. It should help answer the original question.
4	• **Design experiment**	How will you test your hypothesis? What tests will answer your question?
5	• **Test hypothesis / Collect data**	Test your hypothesis by executing your experiments. Collect data from them.
6	• **Interpret / Analyze results**	What do your results tell you? Do they prove or disprove the hypothesis? … It is OK to be wrong.
7	• **Publish findings**	Write papers for conferences & journals. Write dissertation.

Other Variants

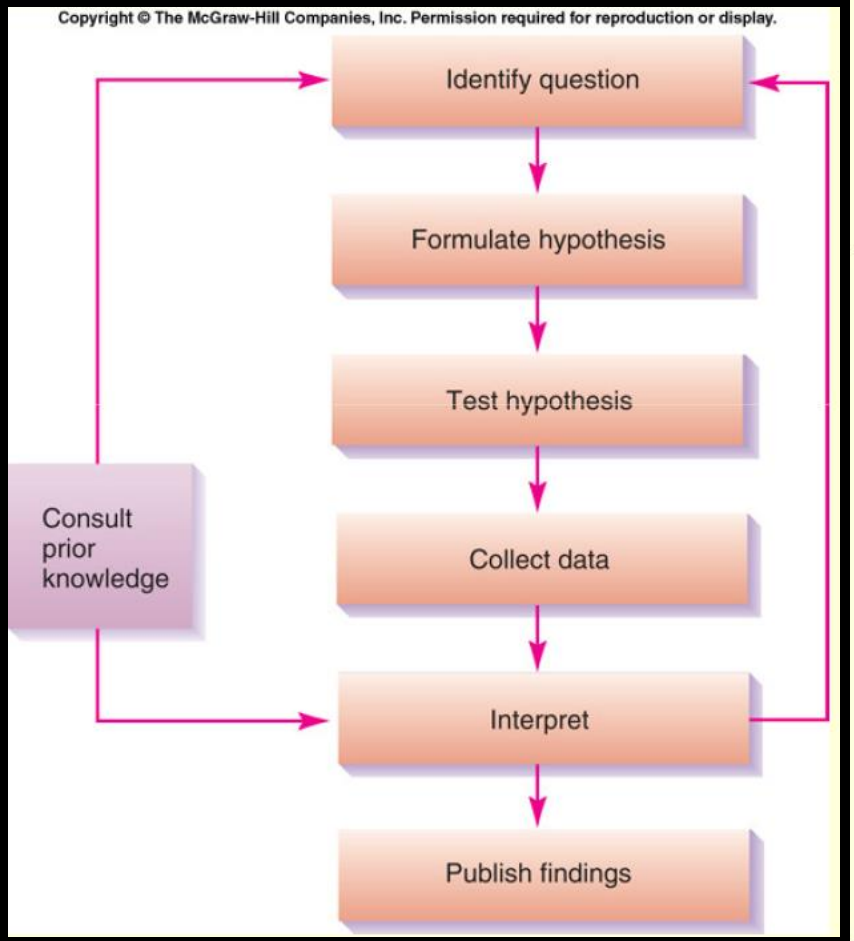


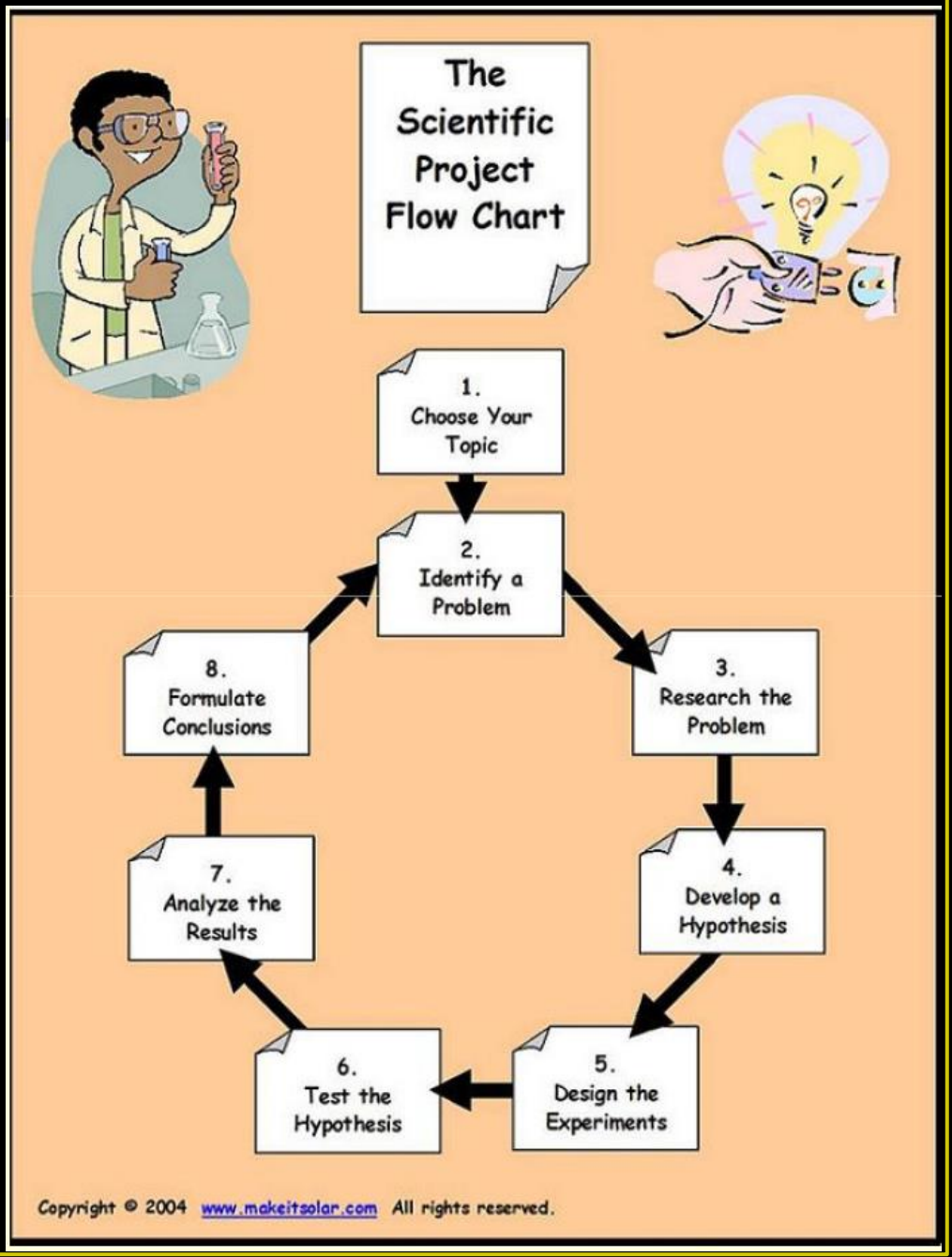
www.sciencebuddies.org/mentoring/project_scientific_method.shtml

1. Define the question
2. Gather information and resources (observe)
3. Form hypothesis
4. Perform experiment and collect data
5. Analyze data
6. Interpret data and draw conclusions that serve as a starting point for new hypothesis
7. Publish results
8. Retest (frequently done by other scientists)

[Wikipedia]

Other Variants





Other Variants

1. **Observe** an event.
2. Develop a **model** (or **hypothesis**) which makes a **prediction**.
3. **Test** the prediction.
4. **Observe** the result.
5. **Revise** the hypothesis.
6. **Repeat** as needed.
7. A successful hypothesis becomes a **Scientific Theory**.

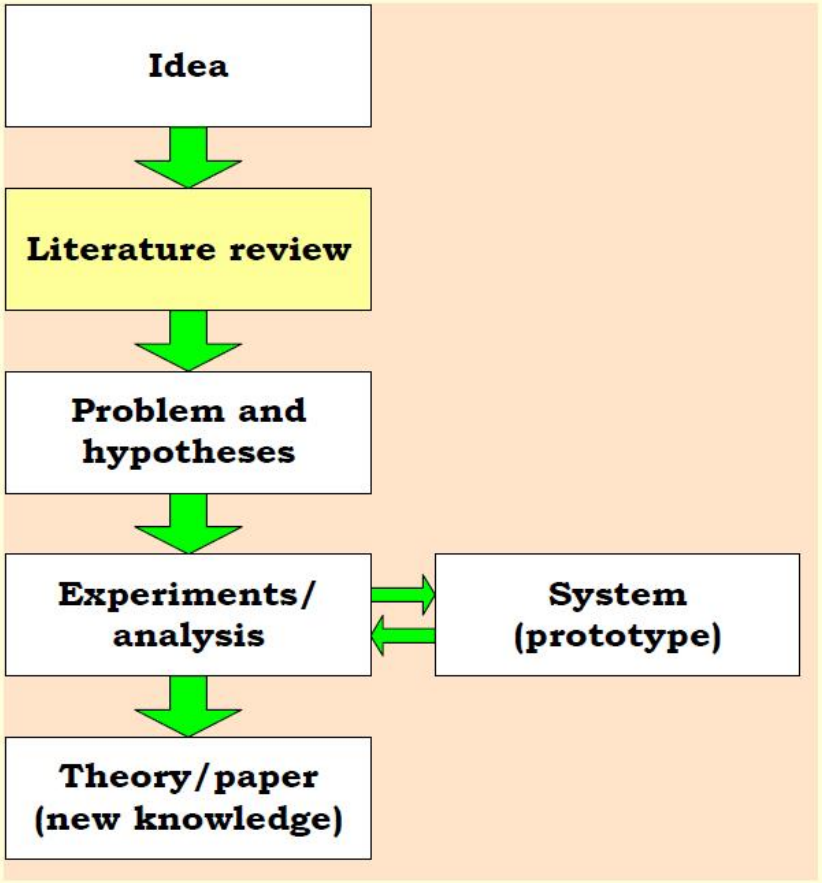
[Nordgren, 2004]

Ask Fred To Act Dramatically Cool

- **A- ask**
- **F- form a hypothesis**
- **T- test hypothesis**
- **A- analyze the results**
- **D- draw conclusions**
- **C- community**

www.gallimorelearning.com/index_files/Powerpoint%20for%20website/Science%20PP/scientificmethod.ppt

Other Variants

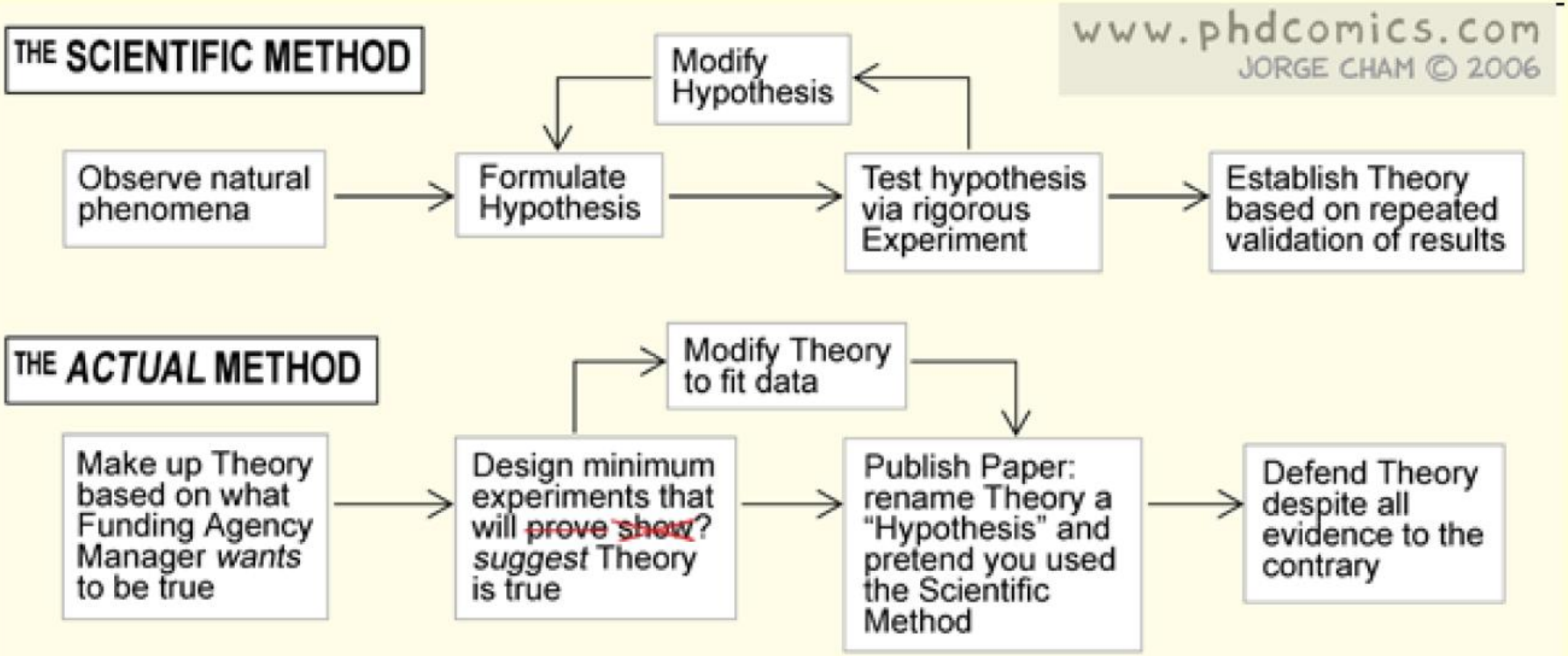


[Mämmelä, 2006]

The Scientific Method Made Easy

http://www.youtube.com/watch?v=zcavPAFiG14

In Practice!


THE SCIENTIFIC METHOD
Modify Hypothesis
Observe natural phenomena
Formulate Hypothesis
Test hypothesis via rigorous Experiment
Establish Theory based on repeated validation of results
www.phdcomics.com
JORGE CHAM © 2006
THE ACTUAL METHOD
Modify Theory to fit data
Make up Theory based on what Funding Agency Manager wants to be true
Design minimum experiments that will prove show? suggest Theory is true
Publish Paper: rename Theory a "Hypothesis" and pretend you used the Scientific Method
Defend Theory despite all evidence to the contrary

Errors of experts who did not follow the Scientific Method

- "Computers in the future may weigh no more than 1.5 tons."
  Popular Mechanics, forecasting the relentless march of science, 1949

- "I think there is a world market for maybe five computers."
  Thomas Watson, chairman of IBM, 1943

- "Airplanes are interesting toys but of no military value."
  Marechal Ferdinand Foch, Professor of Strategy, Ecole Superieure de Guerre.

- "Louis Pasteur's theory of germs is ridiculous fiction".
  Pierre Pachet, Professor of Physiology at Toulouse, 1872

- "Heavier-than-air flying machines are impossible."
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Steps of the Scientific Methods

Step 1: **Formulate Research question / Problem**

- **The most important step in research !**
- **Often comes from the thought:**
  "What we have now is not quite right/good enough – we can do better ..."
- **The research question defines the "area of interest" but it is not a declarative statement like a hypothesis.**
  The central research question may be complemented by a few secondary questions to narrow the focus.
- **Research question must be capable of being confirmed or refuted.**
- **The study must be feasible.**

Research question / Problem - Examples

EXAMPLE (1 single question)

"Which methods and tools should be developed to make current manufacturing control / supervision systems reusable and swiftly modifiable?"

EXAMPLE (multiple questions)

"Q1: What are the main components of logistics costs that determine the logistics and transport network design?
Q2: To what extent are the existing network design and evaluation models sufficient and how can collaboration be incorporated in the network design methodology?
Q3: How can economies of scale and scope, present in the newtork, be taken into account in the network design?
Q4: Is it possible to set boundaries to the development path of the network, and search for a feasible path instead of searching solely for a feasible solution? "

Research question / Problem - Examples

EXAMPLES WITH SOME PROBLEMS:

"The main objective of this work is to contribute to the development of elements of a formal theory for manufacturing systems in order to allow the establishment of a formal methodology for the design and analysis of manufacturing systems"

It states the "idea" ... but is not formulated as a research question ... and sounds vague.

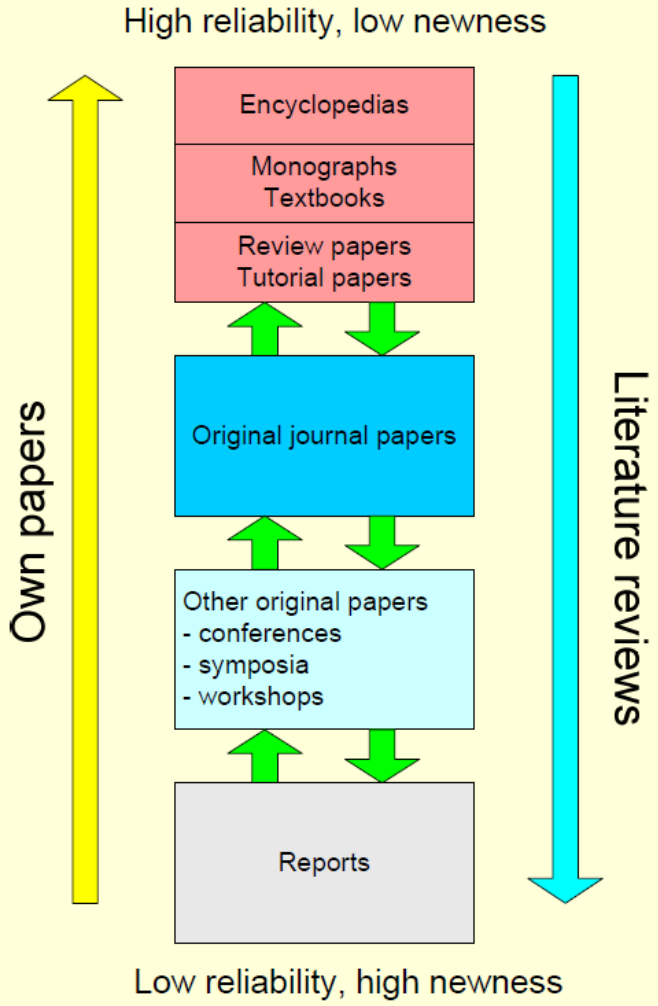
"The main research questions which have guided this research work are:
Q1: Which are the main characteristics of a collaborative network and of a collaborative networked environment?
Q2: How can be assessed the performance of a CN?
Q3: Which are the most relevant conceptual frameworks, architectures, reference models, independent and industry-specific initiatives, ICT platforms and their underlying technologies, targeting interoperability in a collaborative networked environment?
Q4: Which are the main requirements for interoperability in a networked environment?
Q5: How can seamless interoperability be achieved?
Q6: Which are the main differences and similarities between existing conceptual frameworks?
Q7: How can conceptual frameworks be compared, and which are the criteria to support such an analysis and evaluation?
Q8: Do the conceptual frameworks and the technological solutions compete or complement each other?
Q9: Which is the path to be followed to allow heterogeneous and geographically distributed organizations to naturally inter-operate?

Too many, no hierarchy, some redundancy.

Step 2: Background / Observation

- How has the work been done previously? What similar work has been leading up to this point?
  - Study state of the art (literature review, projects, informal discussions, etc).
  - Optional realization of preliminary experiments.
- What distinguishes previous work from what you want to do?
- Who / What will be impacted by this research?

You may iterate between Step 2 and Step 1!



[Mämmelä, 2006]

Step 3: **Formulate hypothesis**

- **A scientific hypothesis states the 'predicted' (educated guess) relationship amongst variables.**

- **Serve to bring clarity, specificity and focus to a research problem**
  - **... But are not essential**
  - **... You can conduct valid research without constructing a hypothesis**
  - **... On the other hand you can construct as many hypothesis as appropriate**

- **Stated in declarative form. Brief and up to the point.**

- **A possible format (formalized):**

  "If ..... then .... (because ....) "

- **In the case of a PhD dissertation, one hypothesis after tested becomes a thesis being defended.**
  - **One dissertation may include more than one thesis.**
  - **Sometimes people refer to the dissertation as the "thesis".**

Characteristics of a hypothesis

- **Should be simple, specific and conceptually clear.**
  ... ambiguity would make verification almost impossible.
- **Should be capable of verification.**
  ... i.e. There are methods and techniques for data collection and analysis.
- **Should be related to the existing body of knowledge.**
  ... i.e. Able to add to the existing knowledge.
- **Should be operationalisable**
  ... i.e. Expressed in terms that can be measured.

Hypothesis example

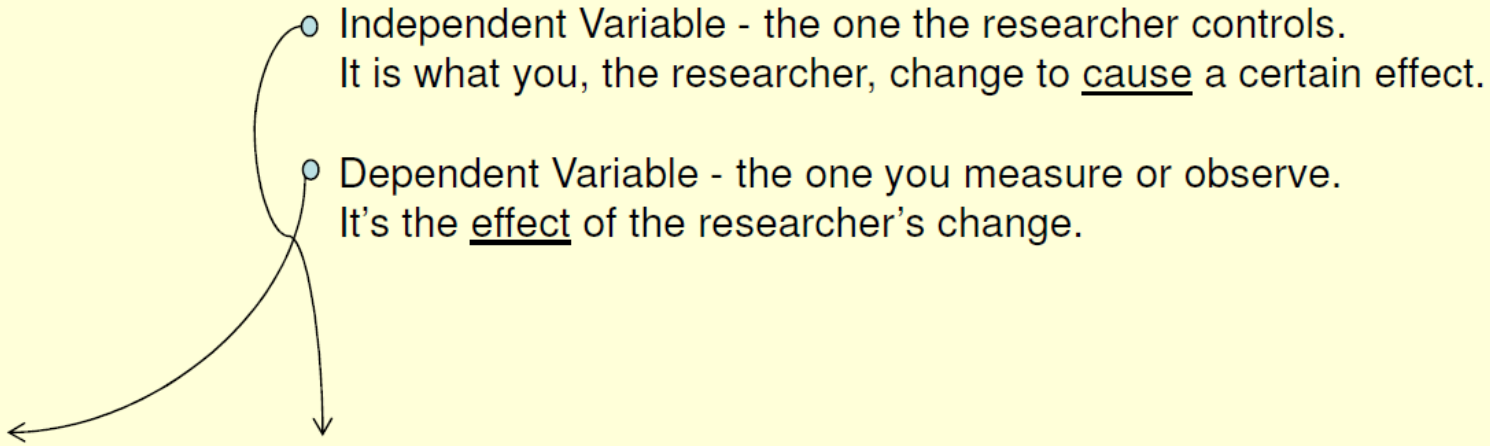
"Shop floor control / supervision reengineering agility can be achieved **if** manufacturing systems are abstracted as compositions of modularized manufacturing components that can be reused whever necessary, and, whose interactions are specified using configuration rather than reprogramming."

Often PhD dissertations fail to make explicit their hypothesis / thesis.

Sometimes the reader can hardly "find" them implicit in a section of "contributions" of the dissertation.

Hypothesis – independent & dependent variables

The hypothesis shall contain two types of variables:
Independent Variable(s)
and
Dependent Variable(s)



"If skin cancer is related to ultraviolet light, then people with a high exposure to UV light will have a higher frequency of skin cancer."

"If temperature affects leaf color change, then exposing the plant to low temperatures will result in changes in leaf color."

Step 4: Design experiment

- **Includes planning in detail all the steps of the experimental phase. In engineering research it often includes the design of a prototype / system architecture.**
- **Identify the variables that will be manipulated and measured – the research outcomes must be measurable. In other words:**
  What needs to be controlled in order to get an umbiased answer to the research question.
- **Therefore: it is necessary to <u>not only</u> design a prototype / system but also the thesis validation method !**
  How to validate the thesis?
- **The plan should allow others to repeat it. It should be feasible...!**
- **Plan intermmediate milestones.**

If you fail to plan, you planned to fail !

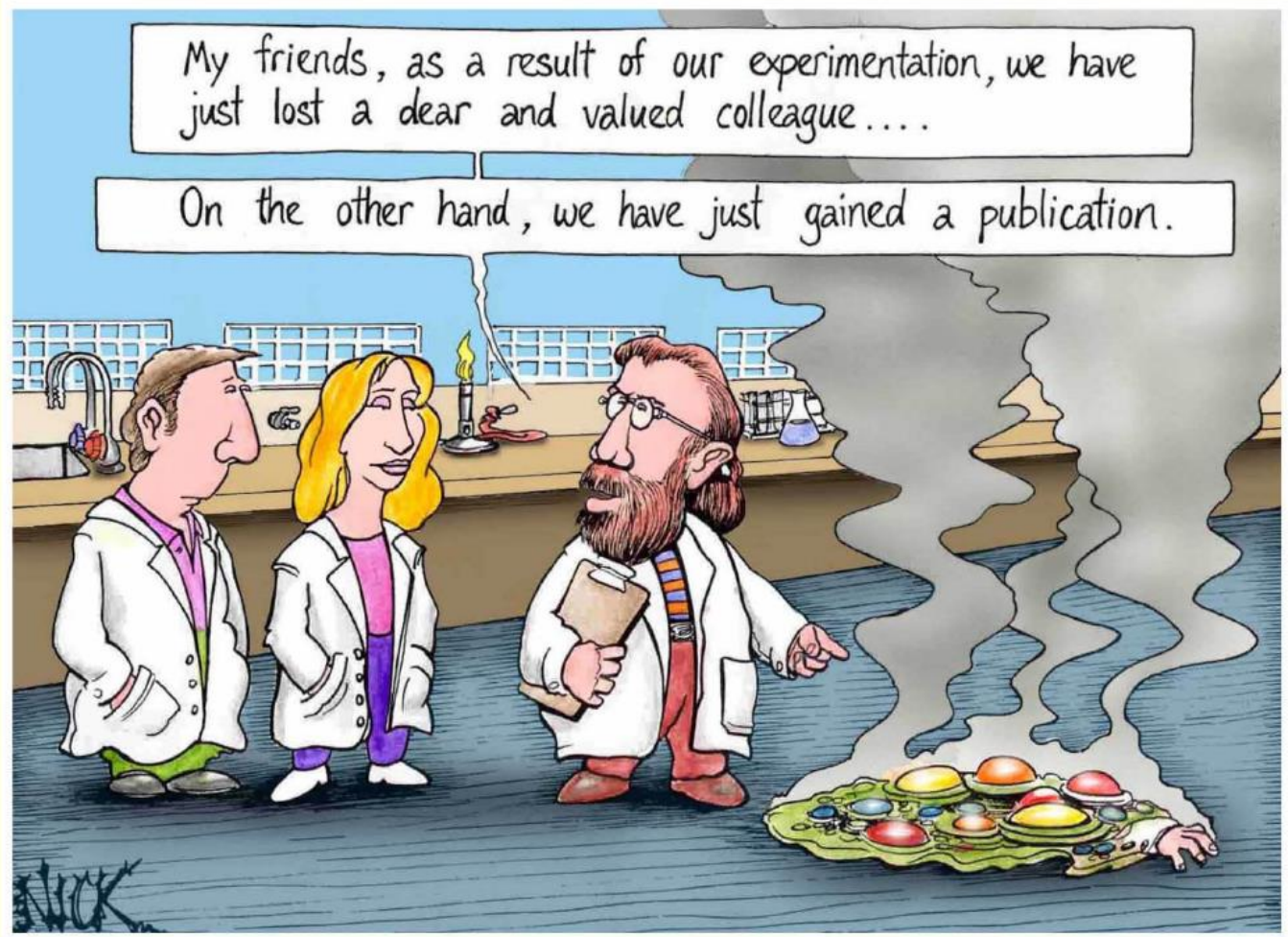
"All sciences are vain and full of errors that are not born of experience, Mother of all certainty, and that are not tested by experience…."

Leonardo da Vinci

Step 5: Test hypothesis / Collect data

- Doing it !
- Implementation of methods (e.g. prototyping) and auxiliary tools (e.g. simulation)
- Pilot testing and refinement.
- Field vs. Laboratory work.
- Any ethical considerations ?
- Confirm results by retesting !

Test hypothesis – perform experiments



Step 6: Interpret / Analyze results

- What did your experiment show?

- Qualitative data analysis.
- Quantitative data analysis.
  - Descriptive and inferential statistics, clustering, ...

- What might weaken your confidence in the results (critical spirit)?

- Discussion regarding
  - Literature
  - Research objectives
  - Research questions.

- Consider next steps
  - Recommendations for further research.

Interpret / Analyze results

Young or old lady?

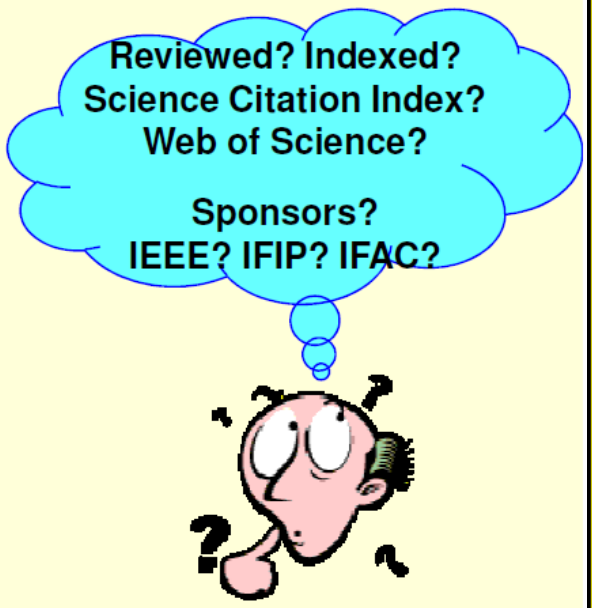
Consider multiple perspectives !

HINT: Use the girls face as the old woman's nose.

Step 7: Publish findings

- A research result is not a contribution to the field if no one knows about it or can use it !
- Write scientific papers, make presentations
  - Intermediate results
    - Conferences
    - Collect feedback
  - Consolidated results
    - Journals
  - Be careful in selecting where you publish !
- Write dissertation

"Publish or perish !"



Attributes of a good thesis

- It should be contestable, proposing an arguable point with which people could reasonably disagree.
  A strong thesis is provocative;
  it takes a stand and justifies the discussion you will present.
- It is specific and focused.
  A strong thesis proves a point without discussing “everything about …”
  Instead of music, think "American jazz in the 1930s" and your argument about it.
- It clearly asserts your own conclusion based on evidence.
  Note: Be flexible. The evidence may lead you to a conclusion you didn't think you'd reach. It is perfectly OK to change your thesis!
- It provides the reader with a map to guide him/her through your work.
- It anticipates and refutes the counter-arguments
- It avoids vague language (like "it seems").
- It avoids the first person. ("I believe," "In my opinion")
- It should pass the “So what? or Who cares?” test
  (Would your most honest friend ask why he should care or respond with "but everyone knows that"?)
  For instance, "people should avoid driving under the influence of alcohol“, would be unlikely to evoke any opposition.

http://www.sdst.org/shs/library/thesis.html

Is it a good thesis ?

How do you know if you've got a solid tentative thesis?

Try these five tests:

- **Does the thesis inspire a reasonable reader to ask, "How?" or Why?“**
- **Would a reasonable reader NOT respond with "Duh!" or "So what?" or "Gee, no kidding!" or "Who cares?“**
- **Does the thesis avoid general phrasing and/or sweeping words such as "all" or "none" or "every"?**
- **Does the thesis lead the reader toward the topic sentences (the subtopics needed to prove the thesis)?**
- **Can the thesis be adequately developed in the required length of the paper or dissertation?**

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MORE: ■ **Can you “prove” it ?**

Proof of concept

"Proof-of-Concept Prototype is a term that (I believe) I coined in 1984. It was used to designate a circuit constructed along lines similar to an engineering prototype, but one in which the intent was only to demonstrate the feasibility of a new circuit and/or a fabrication technique, and was not intended to be an early version of a production design. "

[Carsten, 1989]

http://en.wikipedia.org/wiki/Proof_of_concept

Proof of concept is a short and/or incomplete realization of a certain method or idea(s) to demonstrate its feasibility, or a demonstration in principle, whose purpose is to verify that some concept or theory is probably capable of exploitation in a useful manner. A related (somewhat synonymous) term is "proof of principle".

[Wikipedia]

In applied research a company presented with a project or proposal will often undertake internal research initially, to prove that the core ideas are workable and feasible, before going further. This use of proof of concept helps establish viability, technical issues, and overall direction, as well as providing feedback for budgeting and other forms of commercial discussion and control.

To some extent this applies to the prototyping work done in engineering PhD thesis work.

Presentation languages

- **Is it necessary to include many formulas and equations?**
  Is it not "scientific" if not full of mathematics?

- **There are different "languages" used in different disciplines.**
  - **E.g. Mathematical formulas, Logical formulas / Set theory formalism, Formal specification languages (e.g. Z, Petri Nets), charts, semi-formal diagrams (e.g. UML), etc.**

- **Rigor does not necessarily require formal languages.**
  - **Do not include formulas just to impress the reader !**
    But be rigorous and systematic with what you write !!!
  - **Formal models are useful when the area is reaching a good maturity level and it is the time for knowledge consolidation.**
  - **When planning your research --- and also after analyzing the common practices in your field --- you need to consider the "language" to use.**

Role of simulation

- Simulation is an important tool in engineering and research.
  - In some areas it can cope for unafordable costs with physical experiments
  - It can also help when the performance of the experiment in the real world would take a long period of time (beyond the duration of the research project

- But be careful with its use:
  - How well does the simulation model reflect the reality?
  - You might be inferring conclusions based on “artificial worlds” ...

WRITING A LITERATURE REVIEW

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What is a Literature Review?

- A literature review discusses **published information** in a particular subject area, and sometimes information in a particular subject area within a certain time period.
- A literature review can be just a **simple summary** of the sources, but it usually has an organizational pattern and combines both **summary** and **synthesis.**

What is a Literature Review?

- A **summary** is a recap of the important information of the source, but a **synthesis** is a re-organization, or a reshuffling, of that information.
- It might give a **new interpretation** of old material or combine new with old interpretations.
- And depending on the situation, the literature review may **evaluate the sources** and advise the reader on the most pertinent or relevant.

What is a Literature Review?

- The format of a review of literature may vary from discipline to discipline and from assignment to assignment.
- A review may be a **self-contained** unit -- an end in itself -- or a **preface** to and **rationale for engaging** in primary research. A review is a required part of grant and research proposals and often a chapter in theses and dissertations.
- Generally, the purpose of a review is to **analyze critically a segment of a published body** of knowledge through summary, classification, and comparison of prior research studies, reviews of literature, and theoretical articles.

Why write a Literature Review?

- Literature reviews provide you with a **handy guide to a particular topic**. If you have limited time to conduct research, literature reviews can give you **an overview or act as a stepping stone**.
- Literature reviews also provide a **solid background** for a research paper's investigation. Comprehensive knowledge of the literature of the field is essential to most research papers.

Why write a Literature Review?

- For professionals, they are useful reports that keep them **up to date** with what is current in the field.
- For scholars, the **depth** and **breadth** of the literature review emphasizes the **credibility** of the writer in his or her field

Why write a Literature Review?

- In a broader context Hart (1998) lists the following purposes of a review:
  - **Distinguishing** what has been done from what needs to be done;
  - **Discovering** important variables relevant to the topic;
  - **Synthesizing** and gaining a new perspective;
  - **Identifying** relationships between ideas and practice;
  - **Establishing** the context of the topic or problem;

Why write a Literature Review?

- **Rationalizing** the significance of the problem;
- **Enhancing** and **acquiring** the subject vocabulary;
- **Understanding** the structure of the subject;
- **Relating** ideas and theory to applications;
- **Identifying** methodologies and techniques that have been used;

What should I do before writing the literature review?

- **Clarify**
  - If your assignment is not very specific, seek clarification from your supervisor/lecturer:
  - Roughly how many sources should you include?
  - Should you summarize, synthesize, or critique your sources by discussing a common theme or issue?
  - What types of sources (books, journal articles, websites)?
  - Should you evaluate your sources?
  - Should you provide subheadings and other background information, such as definitions and/or a history?

What should I do before writing the literature review?

- **Find models**
  - Look for other literature reviews in your area of interest or in the discipline and read them to **get a sense of the types of themes** you might want to look for in your own research or ways to organize your final review. You can simply put the word "review" in your search engine along with your other topic terms to find articles of this type on the Internet or in an electronic database. The bibliography or reference section of sources you've already read are also excellent entry points into your own research.

What should I do before writing the literature review?

- **Narrow your topic**
  - There are hundreds or even thousands of articles and books on most areas of study. The **narrower your topic**, the easier it will be to limit the number of sources you need to read in order to get a good survey of the material. Your instructor will probably not expect you to read everything that's out there on the topic, but you'll make your job easier if you first limit your scope.

What should I do before writing the literature review?

- **Consider whether your sources are current**
  - Some disciplines require that you use information that is **as current as possible**. In the sciences, for instance, treatments for medical problems are constantly changing according to the latest studies. Information even two years old could be obsolete.
  - However, if you are writing a review in the humanities, history, or social sciences, a survey of the **history of the literature may be what is needed**, because what is important is how perspectives have changed through the years or within a certain time period.

What should I do before writing the literature review?

- **Find a focus**
  - A literature review, like a term paper, is usually **organized around ideas**, not the sources themselves as an annotated bibliography would be organized. This means that you will not just simply list your sources and go into detail about each one of them, one at a time.

What should I do before writing the literature review?

- As you read widely but selectively in your topic area, consider instead what themes or issues connect your sources together.
- Do they present one or different solutions?
- Is there an aspect of the field that is missing?
- How well do they present the material and do they portray it according to an appropriate theory?
- Do they reveal a trend in the field?
- A raging debate?
- Pick one of these themes to focus the organization of your review.

What should I do before writing the literature review?

- **Construct a working thesis statement**
  - Then use the focus you've found to construct a thesis statement. Yes! Literature reviews have thesis statements as well! However, your thesis statement will not necessarily argue for a position or an opinion; rather it will argue for a particular perspective on the material.

What should I do before writing the literature review?

- Some sample thesis statements for literature reviews are as follows:
  - *The current trend in treatment for congestive heart failure combines surgery and medicine.*
  - *More and more cultural studies scholars are accepting popular media as a subject worthy of academic consideration.*

What should I do before writing the literature review?

- **Consider organization**
  - You've got a focus, and you've narrowed it down to a thesis statement.
  - Now what is the most effective way of presenting the information?
  - What are the most important topics, subtopics, etc., that your review needs to include?
  - And in what order should you present them?

What should I do before writing the literature review?

- Develop an organization for your review at both a global and local level:
- **First, cover the basic categories**
  - Just like most academic papers, literature reviews also must contain at least three basic elements:
    - an **introduction** or background information section;
    - the **body of the review** containing the discussion of sources; and, finally,
    - a **conclusion** and/or recommendations section to end the paper.

What should I do before writing the literature review?

- ***Introduction:*** Gives a quick idea of the topic of the literature review, such as the central theme or organizational pattern.
- ***Body:*** Contains your discussion of sources and is organized either chronologically, thematically, or methodologically (see below for more information on each).
- ***Conclusions/Recommendations:*** Discuss what you have drawn from reviewing literature so far. Where might the discussion proceed?

What should I do before writing the literature review?

- **The introduction** should provide the reader with the **scale** and **structure** of your review. It serves as a kind of map.
- **The body** of the review depends on how you have organized your key points. Literature reviews at postgraduate level should be **evaluative** and not merely descriptive. For example **possible reasons** for similarities or differences between studies are considered rather than a mere identification of them.
- **The conclusion** of the review needs to **sum up** the main findings of your research into the literature. The findings can be related to the aims of the study you are proposing to do. The reader is thus provided with a **coherent background to the current study**.

What should I do before writing the literature review?

- **Organizing the body**
  - To help you come up with an overall organizational framework for your review, consider the six typical ways of organizing the sources into a review:
    - *Chronological*
    - *By publication*
    - *By trend*
    - *Thematic*
    - *Methodological*

What should you write?

- the accepted facts in the area
- the popular opinion
- the main variables
- the relationship between concepts and variables
- shortcomings in the existing findings
- limitations in the methods used in the existing findings
- the relevance of your research
- suggestions for further research in the area.

What should you write?

- **Language focus**
  - Create a balance between direct quotation (citation) and paraphrasing. Avoid too much direct quoting. The verb tense chosen depends on your emphasis:
  - When you are citing a specific author's findings, use the past tense: (found, demonstrated);
  - When you are writing about an accepted fact, use the present tense: (demonstrates, finds); and
  - When you are citing several authors or making a general statement, use the present perfect tense: (have shown, have found, little research has been done).

How to review?

- The whole process of reviewing includes:
  a. Searching for literature
  b. Sorting and prioritizing the retrieved literature
  c. Analytical reading of papers
  d. Evaluative reading of papers
  e. Comparison across studies
  f. Organizing the content
  g. Writing the review

How to review?

- **Comparison across studies**
  - The aim is to extract key points by comparing and contrasting ACROSS studies, instead of reading one paper after another.
  - Key points for a review may concern areas of similarities and/or differences in:
  - Research aim(s) or hypotheses
  - Research design and sampling
  - Instruments and procedures used
  - How data were analysed
  - Results or findings
  - Interpretations

How to review?

- **Pitfalls**
  - Vagueness due to too much or inappropriate generalisations
  - Limited range
  - Insufficient information
  - Irrelevant material
  - Omission of contrasting view
  - Omission of recent work

Example

Early works have addressed some of the problems and issues discussed in video retrieval. Researchers have developed ideas and tools for supporting video editing, for example in [8]. They have defined a seamless video editing in the gradient domain. The spatio-temporal gradient fields of target videos are modified or mixed to generate a new gradient field, which is usually not integrate able. They have also described how semantic information about video can be structured and used for content-based access. From a general video archive point of view, the problem with this tool is the lack of support for managing video document structures. A digital video archive serving different categories of users should offer a more structured way of describing video contents

Example

Hidden Markov Models (HMMs) are statistical tools that have been used successfully in modelling difficult tasks such as speech recognition [15] or biological sequence analysis [16]. Inspired by a similar speech application, Hidden Markov model (HMM) has also been applied to activity recognition. The first approach for the human movements based on HMMs was described in [13]. It distinguished between six different tennis strokes. This system divided the image into meshes and counted the number of pixels representing the person for each mesh. The numbers were composed to a feature vector that was converted into a discrete label by a vector quantizer. The labels were classified based on discrete HMMs. In [8], an HMM is used as a representation of simple actions which are recognized by computing the probability that the model produces the visual observation sequence. In [14] layered HMMs were proposed to model single person office activities at various time granularities

Example

Most of the existing work relies on using only a single source of information (example, either audio or visual track data alone). In [4], the average video shot activity and the duration are used as features for the categorization of movies according to the actions. An action scene was characterized by temporally localized properties of video shots which have little or no recurring similar visual contents [5]. Although these visual characters are undoubtedly good indicators of rapidly evolving action contents, they are not enough to determine the desired action. On the other hand, audio-based action detection was independently performed on the sound track in [6]. However, this audio alone method may lead to many potential false detected cases because many sounds often mix different noises and other similar background sound.

Example

Research	Technique	Features Used	Domain	Disadvantage / Advantage	Future Direction
Lin et al. 2007	A priori algorithm Association rule mining Pre-filtering architecture	Audiovisual	Weather Sports Commercial	Reduce the amount of misclassification errors. Able to identify a high percentage of positive instances in each concept	Due to the different properties of the data sets representing the semantic concepts such as weather, commercial, and sports, they proposed to use different strategies to merge the rules.
Davis & Tyagi 2006	Probabilistic reliable-inference framework Hidden Markov Model (HMM) output likelihoods and action priors Maximum likelihood (ML) and maximum a posteriori (MAP)	Motion	Walking, running, standing, bending-forward, crouching-down, and sitting	The system only makes classifications when it believes the input is 'good enough' for discrimination between the possible actions	

Questions!

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