10. Basic Notions of Science

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1) Exact and technical science

2) Basic and applied research

3) Computer Science and Software Engineering

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Obligatory Literature

► Matti Tedre. Know your discipline: Teaching the philosophy of computer science. Journal of Information Technology Education (JITE), 6:105-122, 2007.

► S. T. Redwine, Jr. and W. E. Riddle. Software technology maturation. In 8th International Conference On Software Engineering (ICSE '85), pages 189-200, Washington, D.C., USA, August 1985. IEEE Computer Society Press.

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Technical Science Solves Practical Problems

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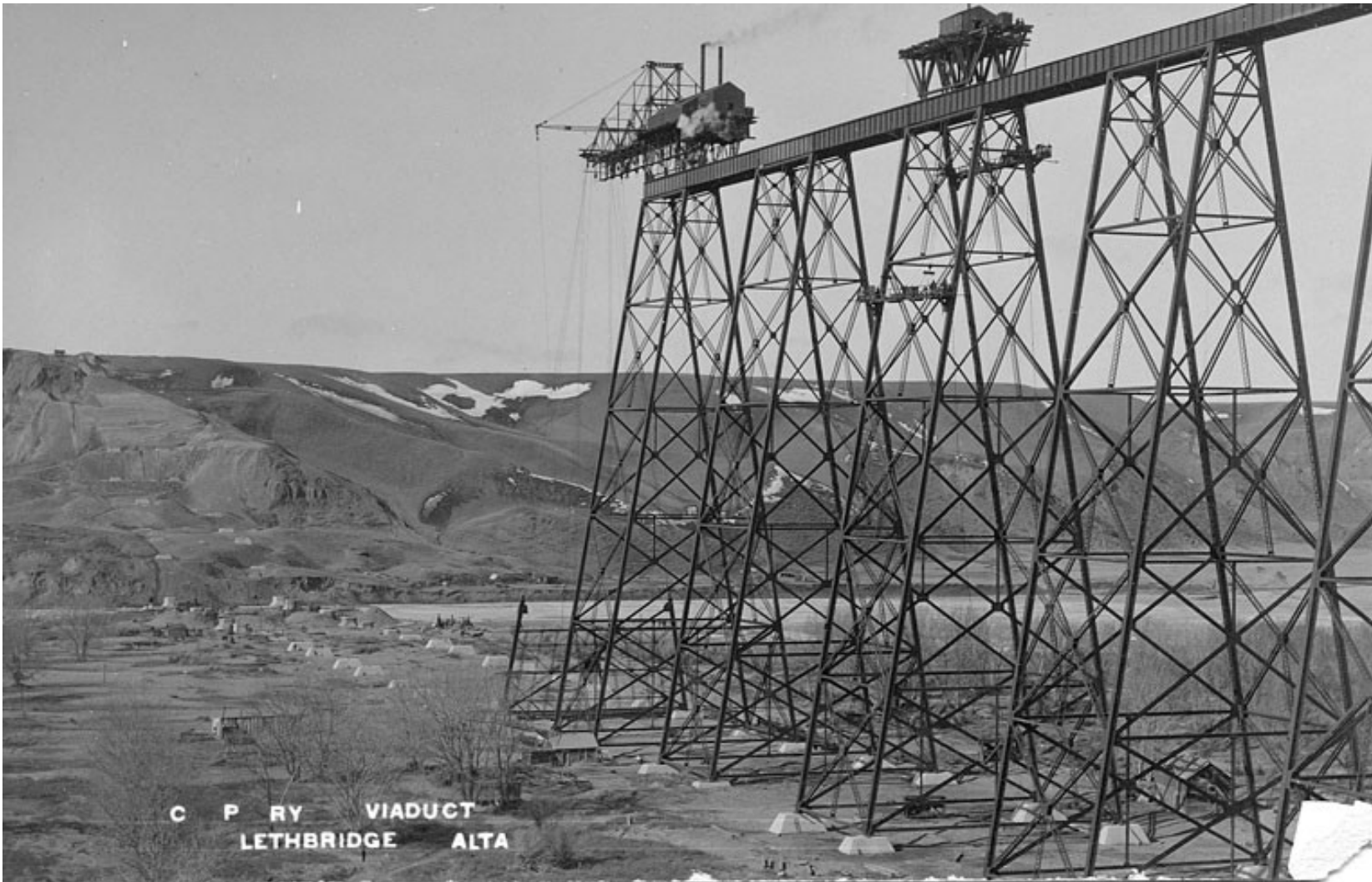
If I have seen further it is by standing on the sholders of Giants.
Isaac Newton

Lethbridge high level bridge. Public domain.
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30.1 Exact Sciences and Technical Science

Exact Science and Formal Science

▶ An **exact science** is any field of science capable of

accurate quantitative expression or precise predictions and rigorous methods of testing hypotheses,

especially reproducible experiments involving quantifiable predictions and measurements.

▶ The **formal sciences [structural sciences]** are the branches of knowledge that are concerned with *formal systems*, such as

  – logic, mathematics, theoretical computer science, information theory, game theory, systems theory, decision theory, statistics, and some aspects of linguistics.

▶ Formal sciences: http://en.wikipedia.org/wiki/Formal_sciences

Exact science but not formal sciences are the natural sciences.

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▶ Die **exakten Wissenschaften** oder auch **harten Wissenschaften** umfassen diejenigen Wissenschaften, die in der Lage sind, genaue *quantitative* oder *mathematisch* oder *formallogisch präzise* Aussagen zu treffen und über eigene, strenge Methoden für die Überprüfung von Hypothesen und vor allem reproduzierbare Versuche mit quantifizierbaren Messungen verfügen.

▶ **Formalwissenschaften (Strukturwissenschaften)** sind Wissenschaften, die sich der Analyse von Formalen Systemen widmen. Von den Formalwissenschaften werden

  – Logik, Mathematik, allgemeine Linguistik und Theoretische Informatik

▶ und von den Naturwissenschaften werden

  – Physik, Chemie, sowie Teile der Biologie

▶ als **exakte Wissenschaften** in diesem Sinne betrachtet.

http://de.wikipedia.org/wiki/Exakte_Wissenschaft
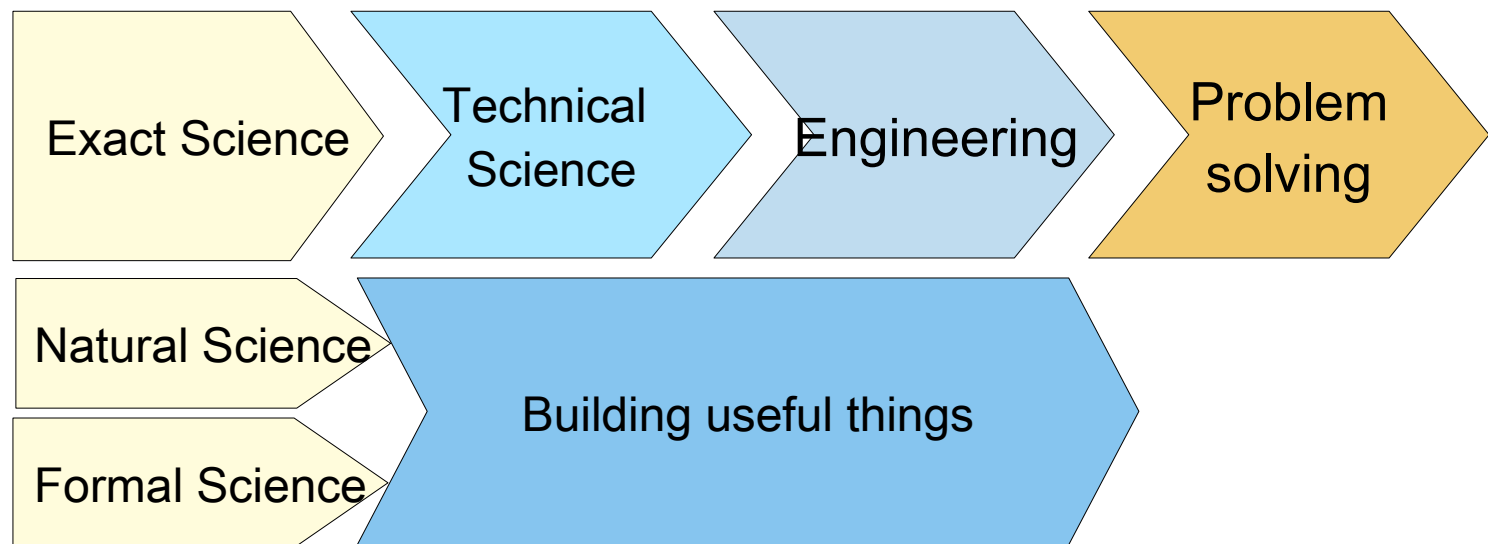http://de.wikipedia.org/wiki/Formalwissenschaften

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Technical Science (Technikwissenschaft)

- **Applied science (Technical science)** uses human knowledge to develop methods and techniques to build or design useful things.

  - Eine **Technikwissenschaft** nutzt die Ergebnisse der exakten Wissenschaften, um Verfahren herauszufinden, nützliche Dinge zu bauen und für den Menschen praktische Probleme zu lösen.

- **Engineering (Ingenieurswesen)** uses the results of technical science to build useful things.

- Technical science must be exact to solve problems!

Exact Science → Technical Science → Engineering → Problem solving

Natural Science
Formal Science → Building useful things

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

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Practical Research vs. Idealized Research

- ▶ [Shaw-ETAPS02] Many research papers and solutions require a *model of reality* in which their result is valid. A **model of reality** is an idealized abstraction of reality

- ▶ An **idealized research problem** is a research problem in a model of reality, a **complete (practical) research** result solves a practical research problem

- ▶ **Structural science** (mathematics, theoretical computer science, computer science) works in idealized model worlds

- ▶ Technical science (engineering science), also Software Engineering, works for **practical problems** and must research **practical solutions**

- ▶ **Technical scientists and Engineers** have to produce **practical solutions**

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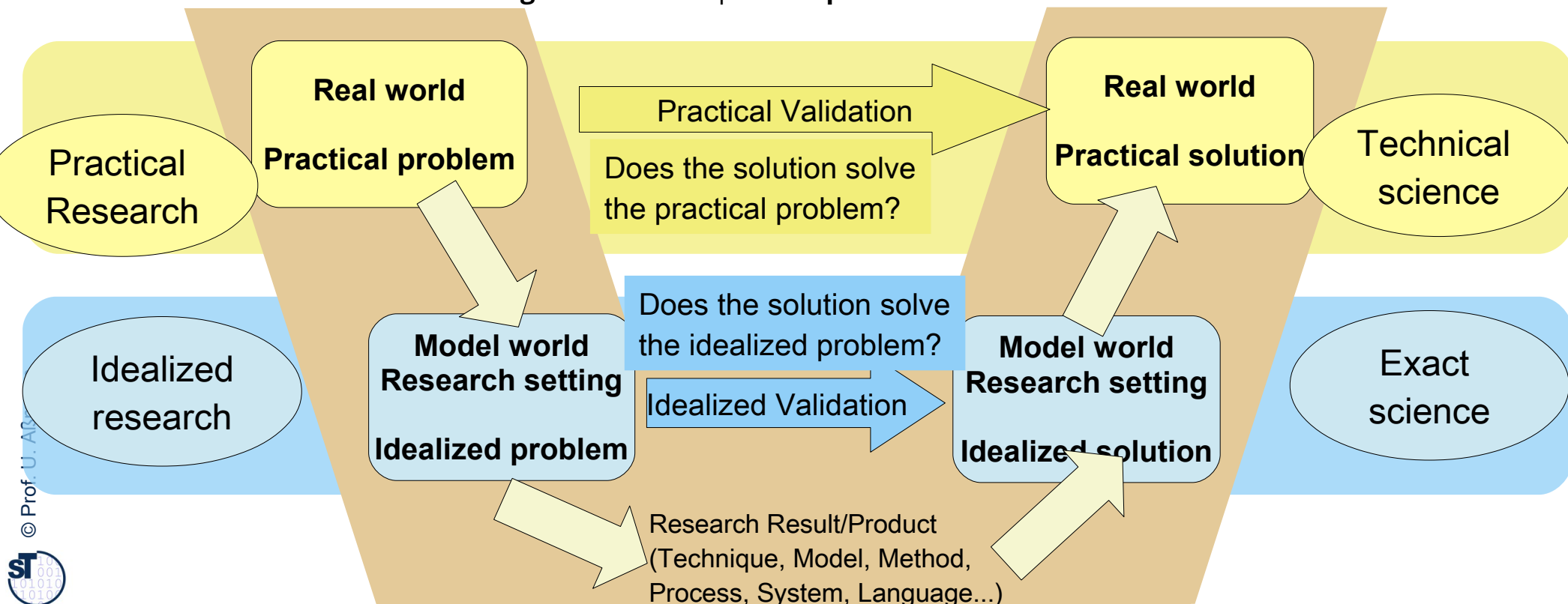
The Beauty of Exact Science

One reason why mathematics enjoys special esteem, above all other sciences, is that its laws are absolutely certain and indisputable, while those of other sciences are to some extent debatable and in constant danger of being overthrown by newly discovered facts."

Albert Einstein

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

The Beauty of Technical Science

"Es gibt nichts Praktischeres als eine gute Theorie." - Kurt Lewin, auch David Hilbert und Immanuel Kant

"Nichts ist praktischer, als eine gute Theorie." - Todor Karman

Eine gute Theorie ist das Praktischste, was es gibt." - Gustav Robert Kirchhoff

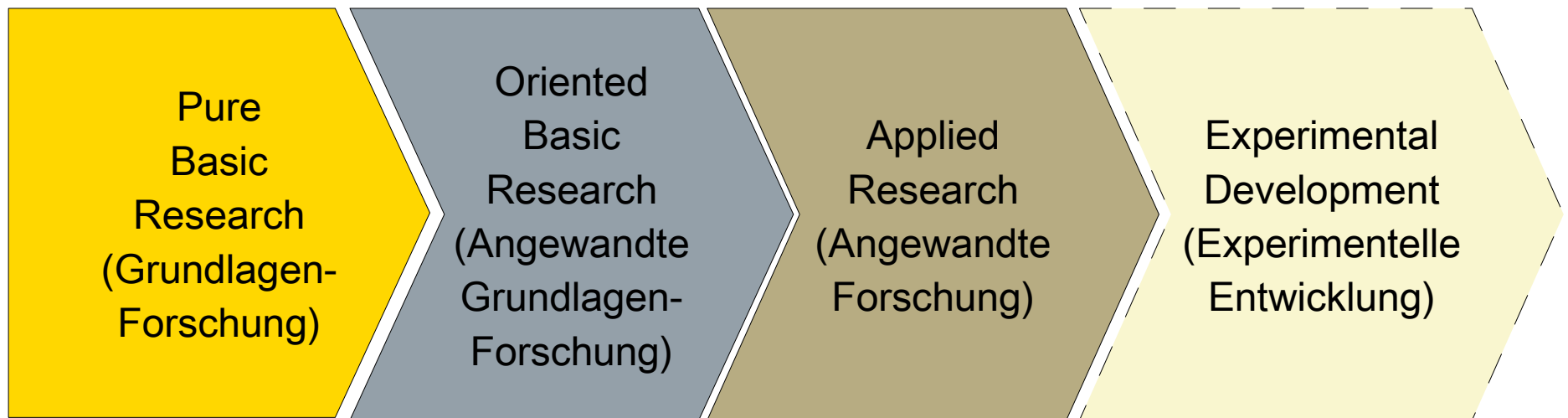http://www.humboldt.hu/HN20/werk.htm

http://de.wikiquote.org/wiki/Diskussion:Theorie

10.2 Different Forms of Research:
Basic and Technology Research

Definition of the OECD 1970

- ▶ The research model of the Frascati-Manual [Töpfer]

- ▶ This is the basis of funding categories for research projects in the EU
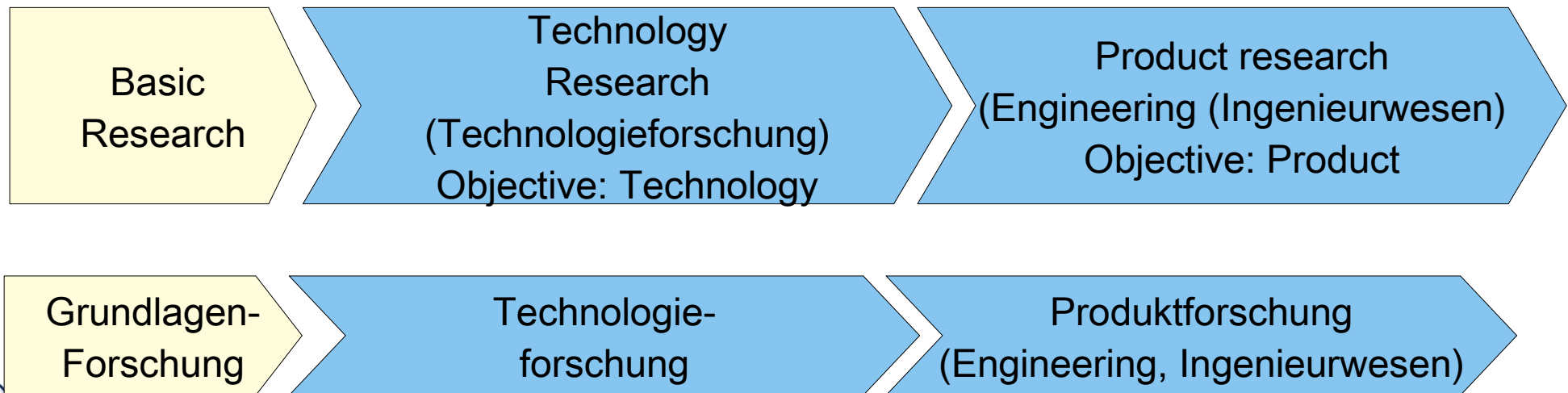
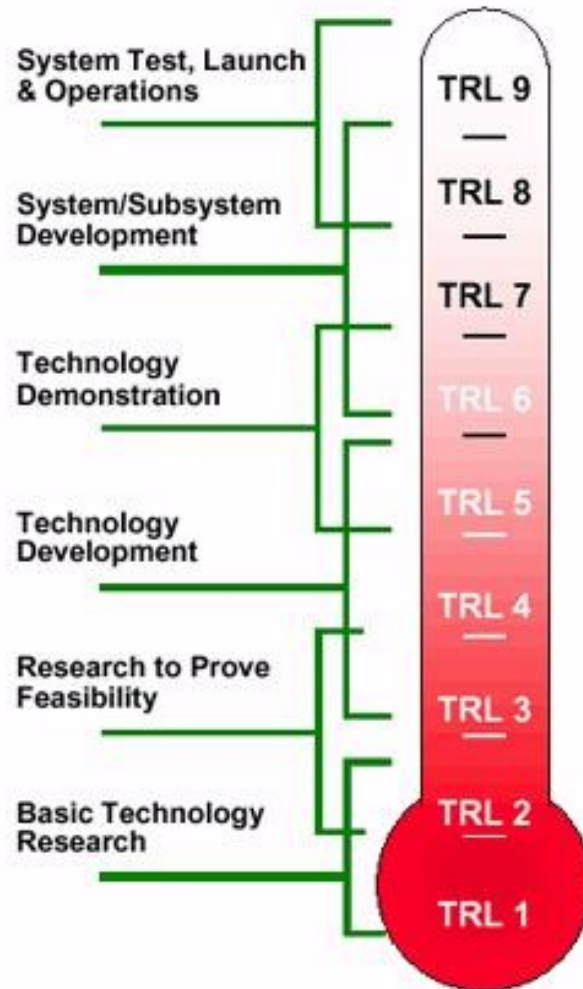 - ▪ Funding rates sink to the right

| Pure Basic Research (Grundlagen-Forschung) | Oriented Basic Research (Angewandte Grundlagen-Forschung) | Applied Research (Angewandte Forschung) | Experimental Development (Experimentelle Entwicklung) |

Basic Research and Technology Science (Technologiewissenschaft): The ResearchModel from [Kopetz]

▶ Basic research is different from research of technologies.

▶ Hermann Kopetz, TU Vienna: In technical sciences, there is basic research, technology research, and engineering:

- **Basic research** is most often structural science (mathematics, theoretical computer science, theoretical physics)

- **Technology science (Technologiewissenschaft)** takes these results and develops methods and techniques for engineering.

- **Engineering (Experimental development, Produktforschung):** Engineers use technologies and results of applied research to experimentally develop prototypes, later products

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System Test, Launch & Operations — TRL 9

System/Subsystem Development — TRL 8, TRL 7

Technology Demonstration — TRL 6

Technology Development — TRL 5, TRL 4

Research to Prove Feasibility — TRL 3

Basic Technology Research — TRL 2, TRL 1

▶ NASA published in 1989 TRL

https://de.wikipedia.org/wiki/Datei:NASA_TRL_Meter.jpg

https://de.wikipedia.org/wiki/Technology_Readiness_Level

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30.3 Computer Science and Software Engineering

▶ Definitions of ACM:

▶ ACM Computing Curricula 2005. The Overview Report covering undergraduate degree programs in Computer Engineering, Computer Science, Information Systems, Information Technology, Software Engineering. The Joint Task Force for Computing Curricula 2005.

- A cooperative project of The Association for Computing Machinery (ACM), The Association for Information Systems (AIS), The Computer Society (IEEE-CS), 30 September 2005

▶ http://www.acm.org/education/education/curric_vols/CC2005-March06Final.pdf

Computer Science

▶ Computer science spans a **wide range**, from its **theoretical** and **algorithmic foundations** to **cutting-edge developments** in robotics, computer vision, intelligent systems, bioinformatics, and other exciting areas.

▶ 3 categories of computer scientists:

- They design and implement software.

- They devise new ways to use computers.

- They develop effective ways to solve computing problems.

What is "Informatik"/"Computer Science"?

▶ Matti Tedre. Know Your Discipline: Teaching the Philosophy of Computer Science

Creating hypotheses/theorems
Proving them
Aim: coherent theories.

Stating requirements and specifications
designing, implementing, testing
Aim: Construct systems, solve problems

Theoretical tradition

Engineering tradition

Empirical tradition
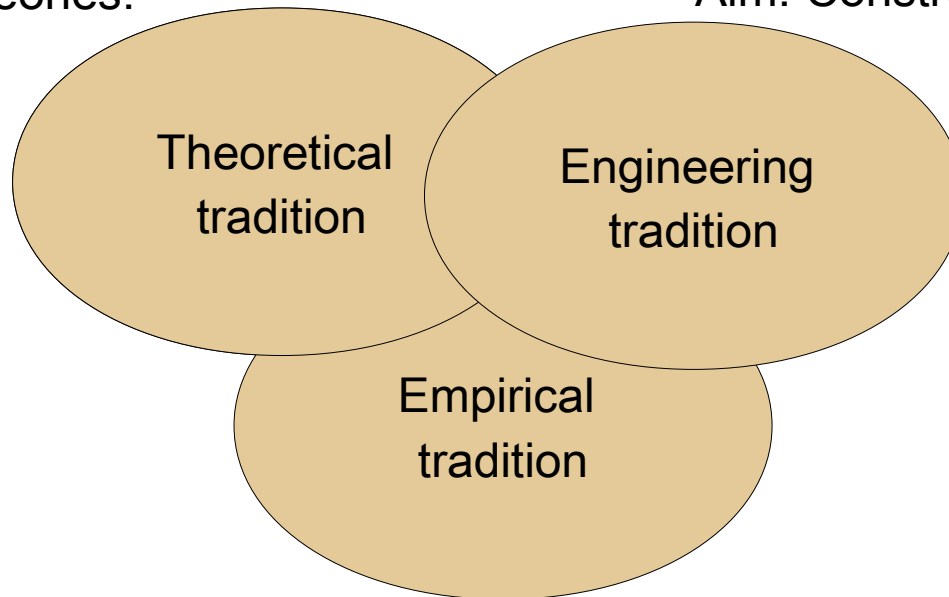
Creating hypotheses, models, predications
Experimenting and collecting data; analyzsing results
Aim: investigate and explain phenomena

Software Engineering

- ▶ Software engineering is the discipline of **developing and maintaining** software systems that behave **reliably and efficiently**, are affordable to develop and maintain, and satisfy all the **requirements** that customers have defined for them.

- ▶ .. it has evolved in response to factors such as the growing impact of **large and expensive** software systems .. in **safety-critical** applications.

- ▶ It seeks to integrate the principles of mathematics and computer science with the **engineering practices** developed for tangible, physical artifacts.

- ▶ Degree programs in computer science and in software engineering have many courses **in common**.

  - – Software engineering students learn more about software **reliability and maintenance** and **focus** more on techniques for **developing and maintaining** software that is **correct** from its inception.

  - – While CS students are likely to have heard of the importance of such techniques, the **engineering** knowledge and experience provided in SE programs go beyond what CS programs can provide.

- ▶ The importance of this fact is so great that one of the recommendations of the SE report is that, during their program of study, students of SE should participate in the development of software to be used in earnest by others.

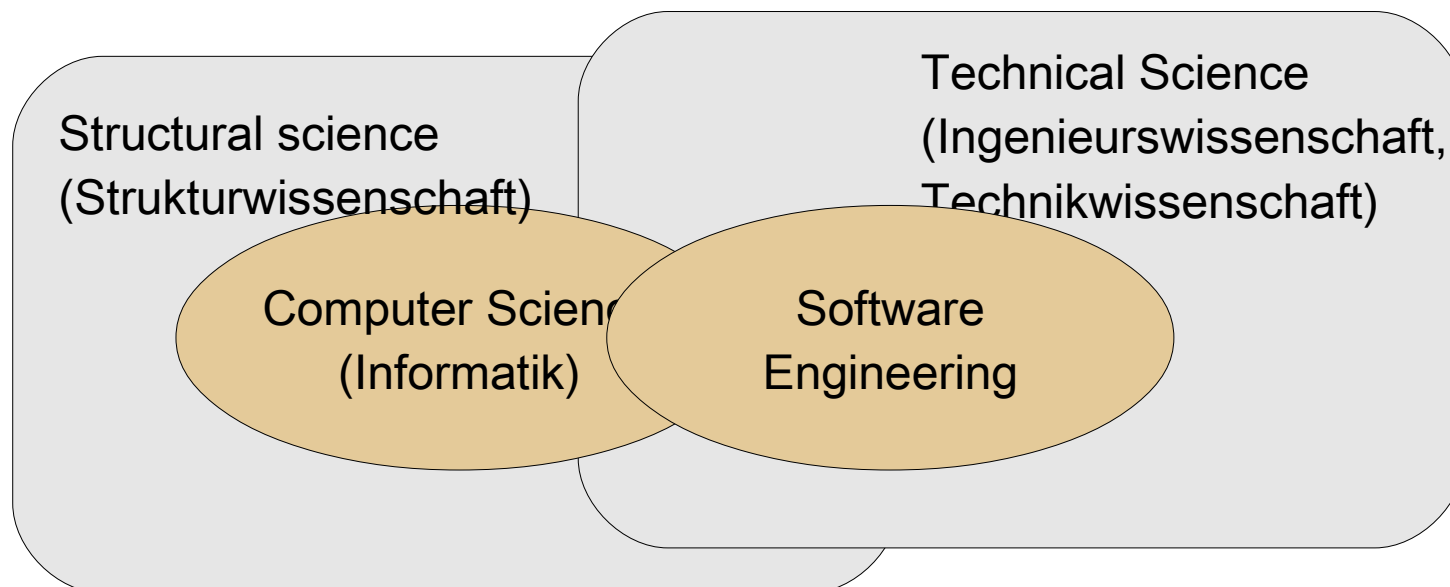# Informatik and Software Engineering

▶ Structural Science

- Analytics

- Descriptive

▶ Technical Science

- Construction

- Models with predictable features

- Application of analytical and descriptive models

Structural science
(Strukturwissenschaft)

Technical Science
(Ingenieurswissenschaft,
Technikwissenschaft)

Computer Science
(Informatik)

Software
Engineering

Specifics of Software Engineering

▶ Management of the architecture of large systems

 – Programming-in-the-large vs programming-in-the-small

▶ Project management

▶ Economic knowhow

 – Costs, Return-on-Investement
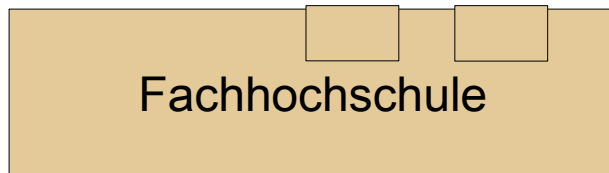
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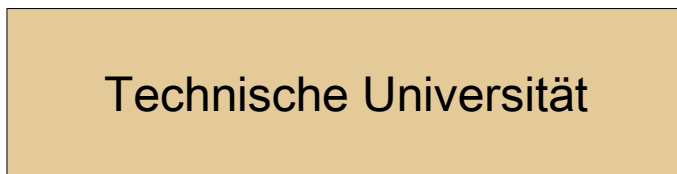
Why are Fachhochschulen (Engineering Schools) Different?

► In Germany, the Bachelor/Master reform has stopped the differentiation of Technical Universities and Fachhochschulen
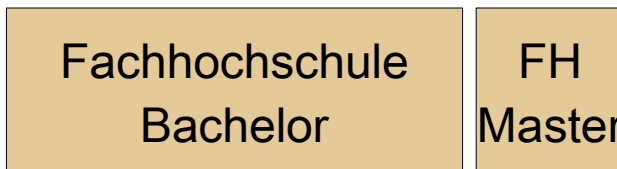
► What is the problem?

Old:

| Fachhochschule | focus on practice of engineering: 2 semester internships in companies |

| Technische Universität | scientific education in a technical science: focus is on method development |

New:

| Fachhochschule Bachelor | FH Master | focus on ?? 2 semester internships in companies lost 1 year master doesnt deserve the title |

| Technische Universität | TU Master | Vordiplom (school) is now 3 years Interchangeabilty is not really guaranteed engineering and technical science are no longer distinguished! |
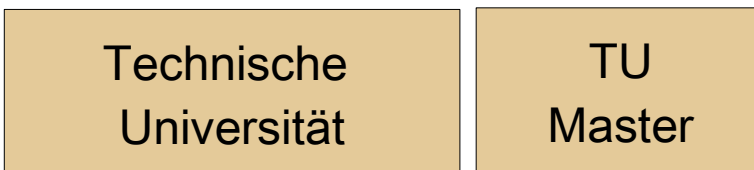
One problem is that the difference of engineering and technical science (Ingenieurswissenschaft) has been forgotten

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The End

▶ Explain the differences of

- Basic research and technology research

- Structural science and technical science

- Computer science and software engineering

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