Generalisability in Science Education Research

FontD Seminar 2004 in Mälardalens Högskola

Eskilstuna October 1

Universität Bremen

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Part 1

Theoretical aspects about generalisability

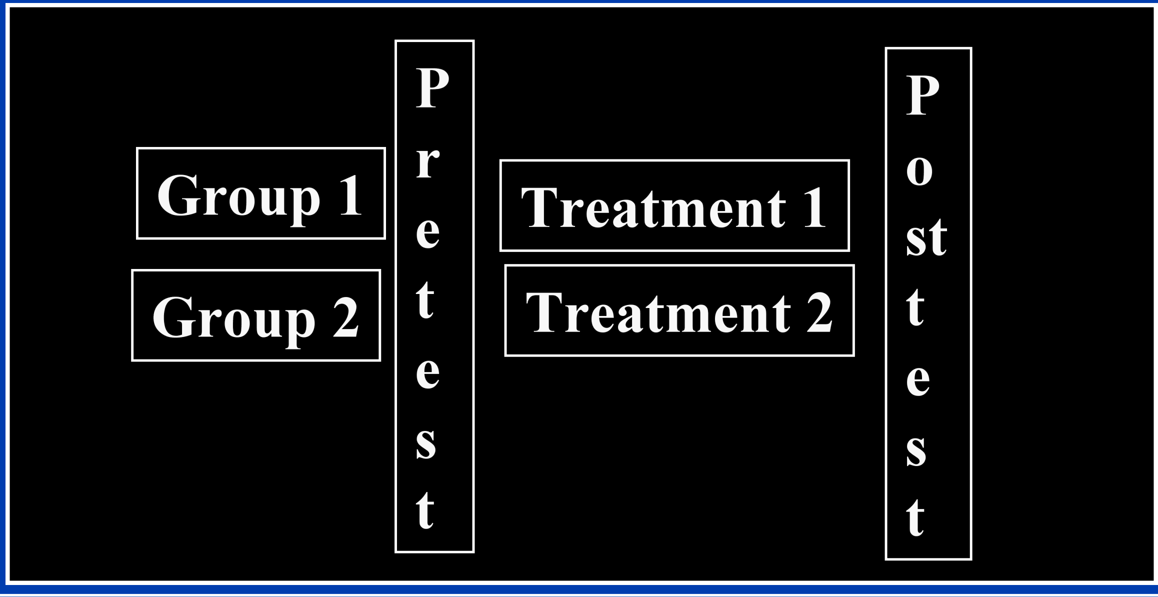
Aspects of generalisability

- Aspect 1: Statistics and classical quantitative design
- Aspect 2: Generalisability as essential feature of theory
- Aspect 3: Generalisability and paradigm (Kuhn);
  Generalisability as acceptance in the
  scientific community

Aspect 1:
Statistics and classical quantitative design

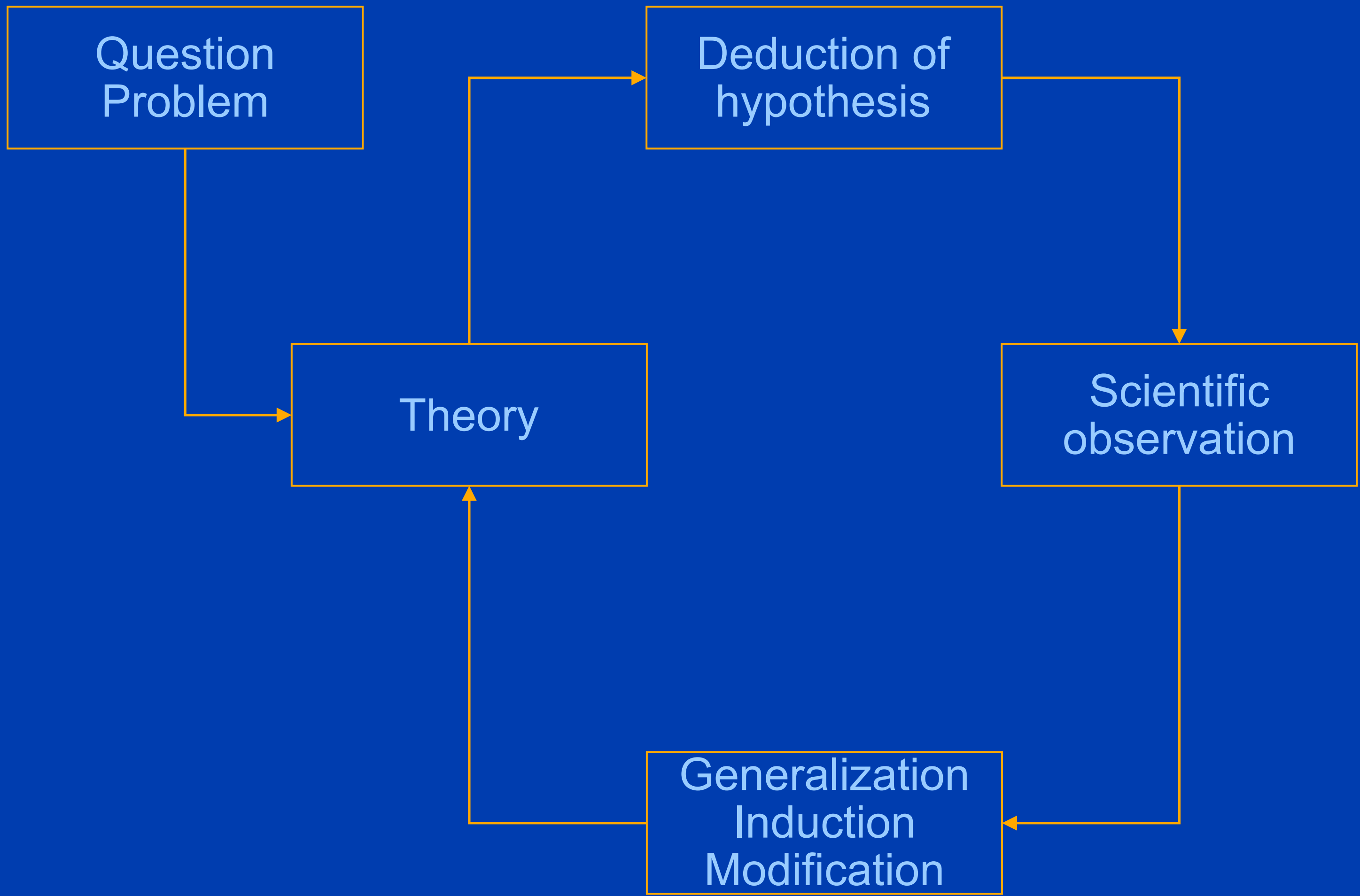
- Petri 1996: ONE Student
- Hake 1998: 5000 students

Aspect 1:
Generalisability guaranteed by design?



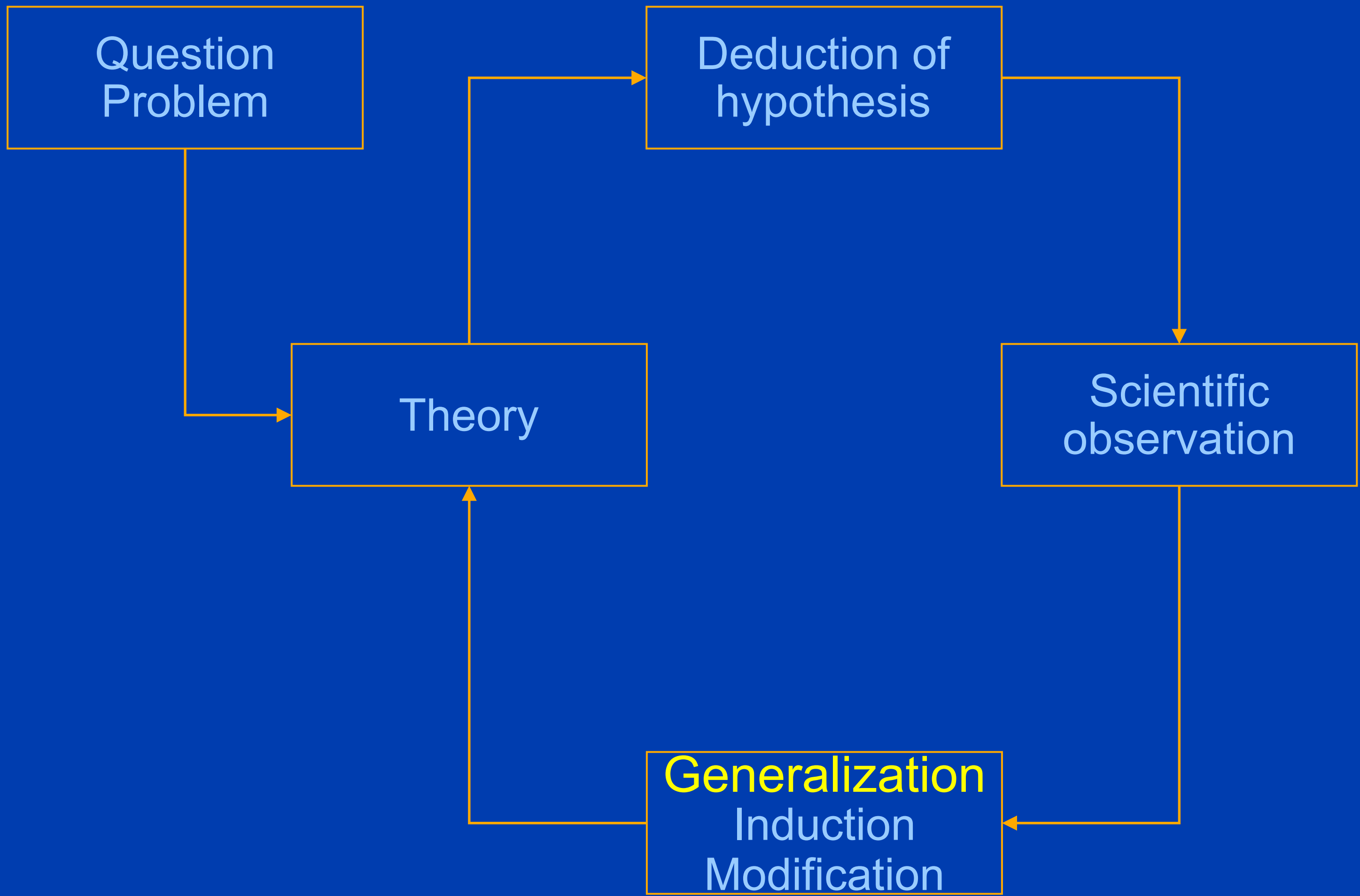
- **Weaknesses of case studies (Wirth & Leutner 2004)**
  - **… No discovery of a universal, generalizable truth**
  - **… No discovery of a cause-effect relationship**
  - **… Not appropriate for testing hypotheses**
- **I could think of cases: with/without computer, with/without electronium**

General empirical approach (Wirth & Leutner 2004)



Internal Validity

General empirical approach (Wirth & Leutner 2004)



Internal Validity

=> "External validity"

External validity

- Extent to which conclusions drawn from a scientific observation can be generalized to other persons, situations or points of time.
- Control
  - environmental conditions,
  - real life setting,
  - representative sample,
  - replication (in different contexts),
  - theory use

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Possibilities in science education

Where we have strong hypotheses from previous qualitative research ...

- Investigate the effect of using an electronium model of the atom compared to a course using a propability model of the atom
- Doing similar courses in optics with and without using different kinds of computer software

◆ Example: In Roger's dissertation project at KAU, we try to develop a classical design, using different treatments with different use of ICT in optics

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Aspect 1:
Statistics and classical quantitative design

- Generalisability ...
  seen as a problem of design and statistical evidence.

Aspect 2:
Generalisability as essential feature of theory

Reif, F., Larkin, J. H. (1991)
Cognition in Scientific and Everyday Domains:
Comparison and Learning Implications,
JRST Vol. 28, NO. 9

Domain goals	Everyday domain	Scientific domain
Main goals		
Central goal Subgoal	Leading a good life Adequate prediction and explanation	Optimal prediction and explanation
Requirements	Adequate generality, parsimony, precision, consistency	Maximal generality, parsimony, precision, consistency

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Aspect 2:
Generalisability as essential feature of theory

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Domain goals	Everyday domain	Scientific domain
<u>Main goals</u>		**Incl. Science education !**
Central goal Subgoal	Leading a good lif Adequate predicti explanation	
Requirements	Adequate generali parsimony, precisi consistency	

Maximal generality, parsimony, precision, consistency

- Little generalisability in EDL thinking ("cluster concepts")
- "Generalisability as definition of science" (Reif, Larkin, Schecker, Niedderer)

Example of working for more generalisability

- In **Margareta**'s work about ownership we are working hard on a **better theoretical definition of the concept of ownership**, with maximal
  - Generality
  - Parsimony
  - Precision
  - Consistency
- Furthermore we try to define in such a way that it has predictive power.
- No statistics will be needed in this task.

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Aspect 2:
Generalisability as essential feature of theory

- Generalisability ...
  seen as amount and quality of use of theory.

Theory with general concepts

- Try to come to general definitions of concepts: use the same definition for every case, not one definition in one case and a different definition in an other case (as we would all do it in everyday life context!)
- Similar: work on general claims or hypotheses
- Try to build up confidence by telling frequencies - how often you were able to apply this concept - in qualitative work - and how often you were unsure about it. A negative statement - category does clearly NOT fit - is a positive statement in this sense!

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Aspect 3: Generalisability as acceptance in the scientific community

T. S. Kuhn distinguishes three phases of development of a scientific theory:

- the pre-paradigmatic phase: Many different questions, many "theories", little generalisability
- the paradigmatic phase, high generalisability of paradigmatic research
- the revolutionary phase: generalisability of the new paradigm takes time to build up.

Aspect 3: Generalisability as acceptance in the scientific community

- In the paradigmatic phase of research, there are agreed
  - questions
  - concepts
  - repeated and agreed results
  - meanings
- In SER we have at least one such field: alternative conceptions of learners
  - Many Swedes contributed to it (B. Andersson, ..., F. Marton)
- This gives a body of agreed knowledge which gives the highest amount of generalisability (Generalisability by cummulation in the scientific community)

Number of investigations in Pfund&Duit

duit@ipn.uni-kiel.de

Topic	1991	1994	1998
Mechanics	281	421	687
Electricity	146	218	379
Heat	68	111	159
Optics	60		162
Particles	69		190
Energy	69		151
Astronomy	36		
Quantum Physics	11	35	57

R. Duit: Bibliography "Students' Alternative Frameworks and Science Education" Aug. 2002

1998

> 4000 entries alltogether

Part 2

Cases

Cases

- Case 1: 6000 students study by Hake (1998)
- Case 2: Doctoral study of Bethge (1988)
- Case 3: Doctoral study of Petri (1996)

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Case 1: Empirical Results Hake 1998

- **Interactive-engagement vs traditional methods**
  A six-thousand-student survey of mechanics test data for introductory physics courses
  R. Hake, Am.J.Phys. 1998 (1)

Traditional methods

- "Traditional" (T) courses as those reported by instructors to make little or no use of IE methods, relying primarily on
- passive-student lectures
- recipe labs, and
- algorithmic-problem exams

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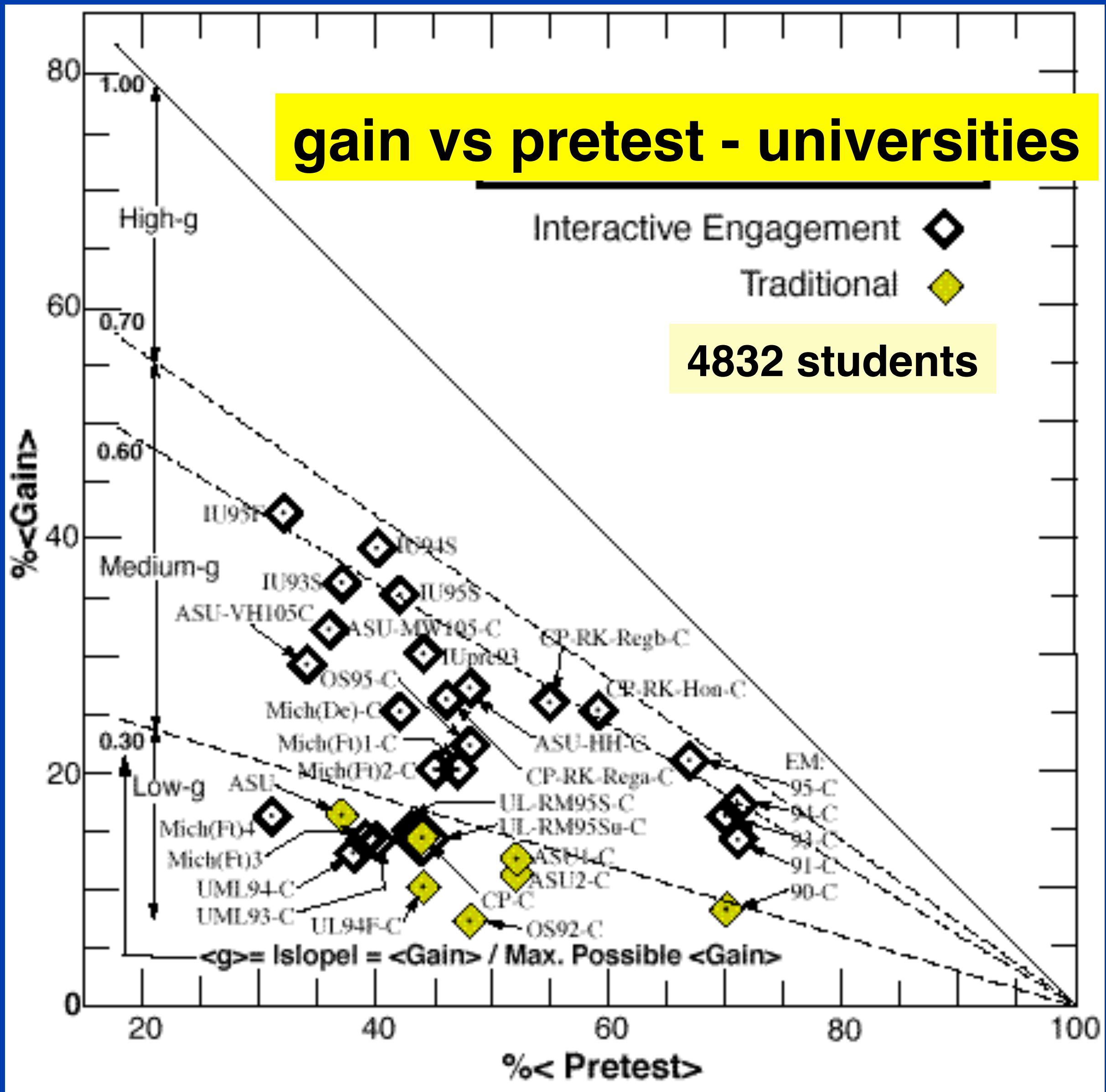
“Interactive Engagement” (IE)

Methods as those designed at least in part to promote

- conceptual understanding through interactive engagement of students
- in "heads-on" (always) and
- "hands-on" (usually) activities
- which yield immediate feedback through discussion with peers and/or instructors

Interactive-engagement vs traditional methods



$$G = \%post - \%pre$$

G in %

$$g = \frac{\%post - \%pre}{100 - \%pre}$$

g < 1

Generalisability in case 1

Aspect 1: Statistics and design

- 6000 students is very impressive
- Control of variables?
  "interactive teaching as reported by the teachers"
  and
  "better understanding as measured by the FCI"?
  More qualitative tasks related to alternative conceptions about force?
  FCI measures only one aspect of competence, namely qualitative, multiple choice tasks related to many different alternative conceptions (not only Newton's force)

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Generalisability in case 1

- **Aspect 2:**
  Generalisability as essential feature of theory
  - General theoretical claim
  - Overgeneralised? Other factors not taken into account?
- **Aspect 3:**
  Generalisability as acceptance in the scientific community

Case 2: Students' alternative conceptions in atomic physics (Bethge 1988)

Case 2: Students' alternative conceptions in atomic physics (Bethge 1988)

Methods

- 1) Audio recordings of current physics lessons were our main data source.
- 2) A pair-relation questionnaire with associative elements. In this type of questionnaire students were asked to make statements using two given concepts, for example:
  - wave - energy level
  - wave function - trajectory
  - trajectory - energy level
  - position - wave function
  - electron - wave
  - trajectory - probability
- 3) A questionnaire with seven "thinking type" tasks
- 4) Interviews with nine pairs of students

Conceptions related to orbits (trajectories) in quantum physics after teaching

(O1) Classical orbits (about 50%)

(O2) Only special orbits allowed

about 25%

(O3) Smeared orbits

The concept of "trajectory" is combined with notions of "probability" and "wave function" from wave mechanics in several ways to form a new "intermediate" conception:

- the orbits are "smeared", not exactly determined, "fuzzy"
- the probability for a special orbit is given
- the probability of parts of the orbit is given

(O4) Trajectories do not exist in quantum physics (about 25%)

Generalisability in case 2

Aspect 1: Statistics and design

- Criteria of Wirth & Leutner
  - external validity, generalisability to other persons, situations or points of time, representative sample: This research was with data from many students and classes,
  - real life setting: with data from real teaching
- The results seem thus be generalisable from a statistical view with respect to 17 to 19 age students, after teaching in atomic physics with more than Bohr's model

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Generalisability in case 2

- **Aspect 2:**
  Generalisability as essential feature of theory
  - **General theoretical claim: students also in quantum atomic physics show a limited number of alternative conceptions. Some of these are ...**
- **Aspect 3:**
  Generalisability as acceptance in the scientific community
  - **Replication in different contexts (Aspect 1) and cummulation (Aspect 3)**
  - **... was done to some extent later by dissertations (Lichtfeldt 1992, Mashhadi 1996, Deylitz 1999) and other research (Harrison et al. 1999, Müller et al. 2002)**
- **So the results are - today ! - partially generalisable**

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Case 3: Learning pathways in atomic physics (Petri 1996)

- Building on theoretical ideas in the community
  - Driver 1989, Scott et al. 1991: conceptual pathways
  - Bremen workshop 1991: need to describe learning pathways
    "(1) Need to document learning pathways
    for different content areas in physics"
    "(2) Need to construct ways of describing cognitive systems
    that are useful to researchers in physics education"
  - Niedderer (1991 to 1996): Prior example electric circuits
  - Psillos 1999: Conceptual evolution
- Giving ONE example in great detail
  (analysing huge amount of data from ONE student)

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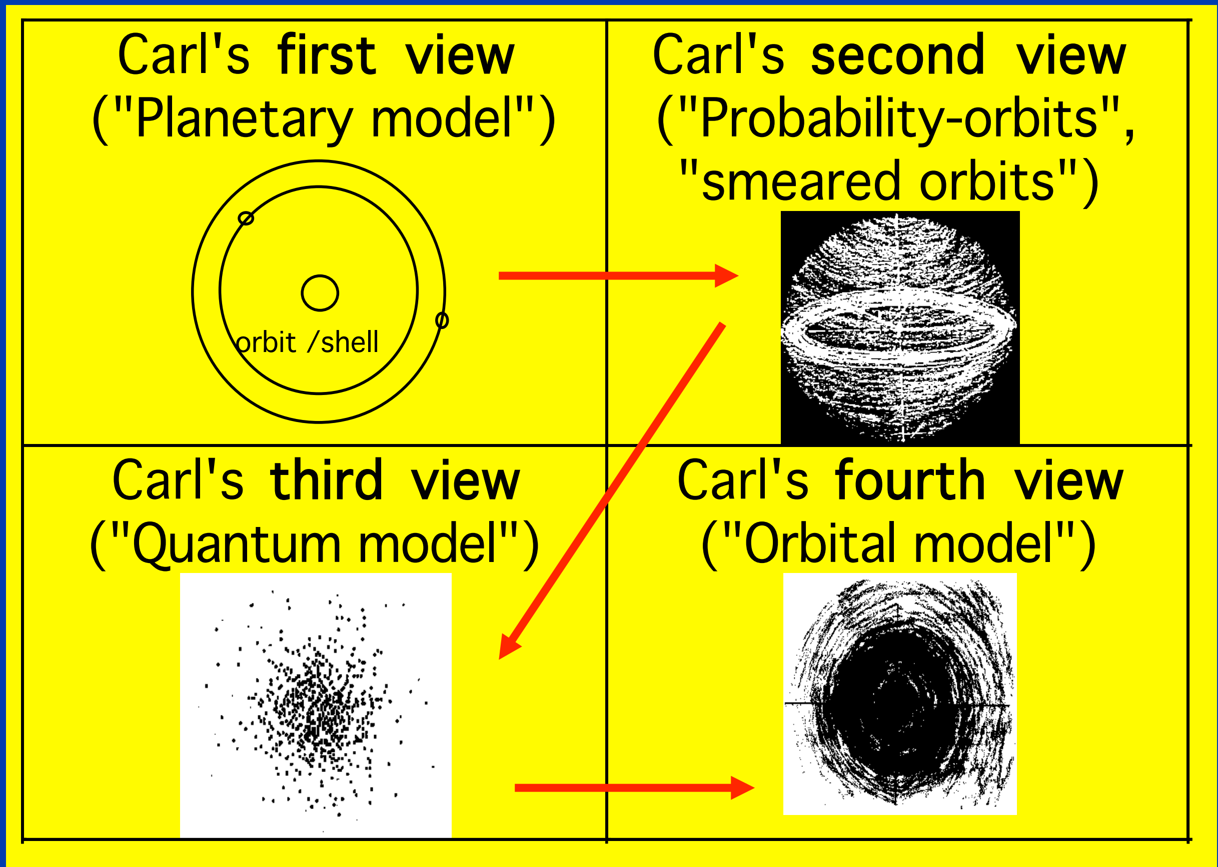
Carls Learning Pathway “Modell of the Atom"

Petri 1996; Petri&Niedderer 1998

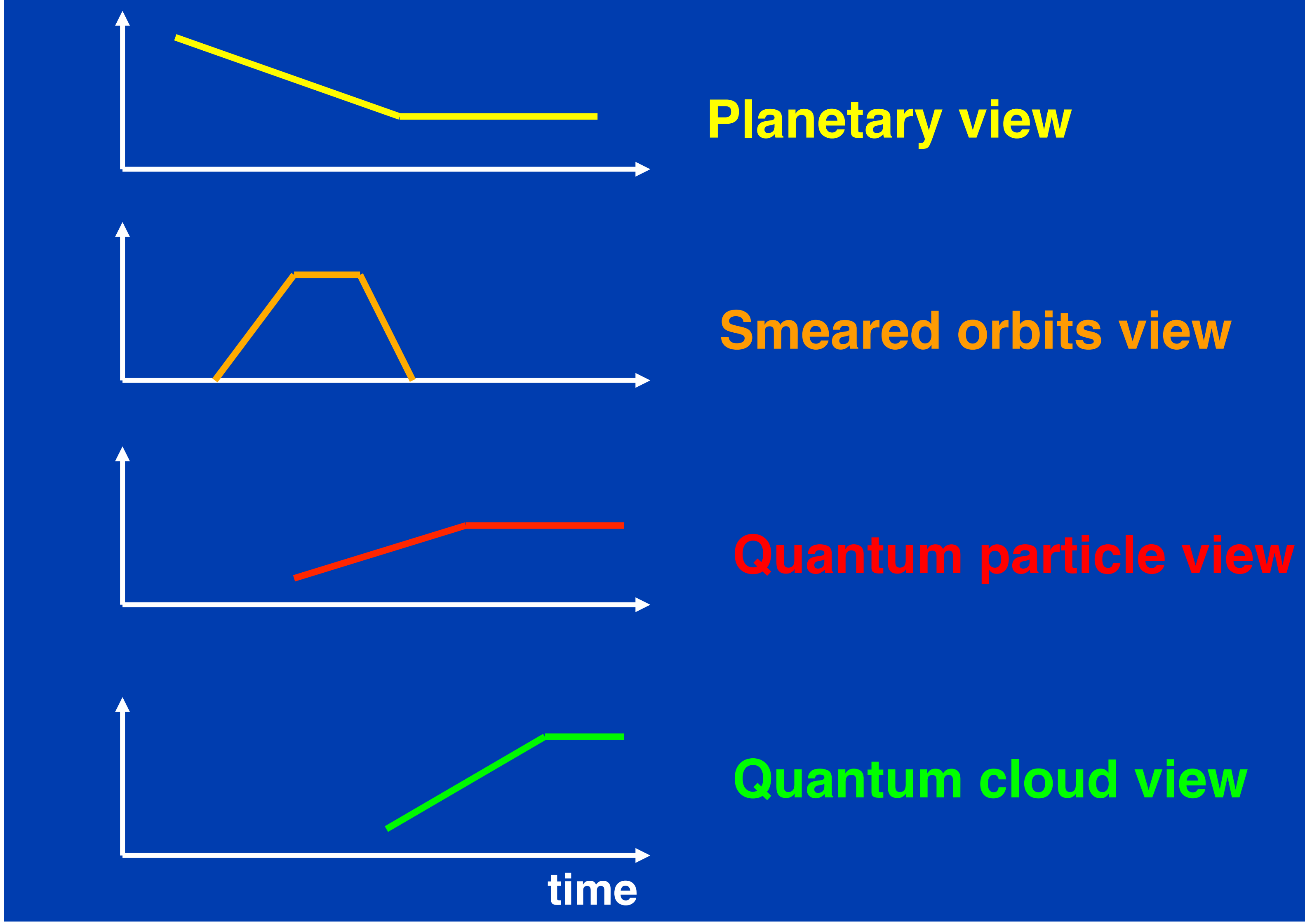


Example of working for more generalisability

- In developping a new dissertation project at MdH, **Peter Gustavsson** and I are planning to have a new doctoral student working on a **learning pathway for a whole class** in distant education.

An advanced model of the learning process

Example: conceptions of an atom



Generalisability in case 3

- **Aspect 1: Statistics and design**
  - 1 student: No generalisability to other students
- **Aspect 2:**
  Generalisability as essential feature of theory
  - Showing new, general model of a "learning pathway" as a theoretical idea (GENERALISABILITY-claim!)
    in ONE example in great detail, thus making it work!
    Holzkamp: An experiment is a realisation of theory.
- **Aspect 3:**
  Generalisability as acceptance in the scientific community
  - The theoretical ideas were later used - and cited - by other researchers
    (Psillos 1999 "conceptual evolution"; Taber (2000) "manifold conceptions in cognitive structure")

Part 3

Conclusions

Final conclusion

- Try to come to theoretical definitions of concepts and claims, thus building up potential generalisability
- Generalisability is a decision of the community of researchers, developping a paradigm (Kuhn), coming to paradigmatic research
- This decision is based on empirical research in combination with normative decisions about relevant questions and theoretical approaches
- To formulate it the other way round:
  I do not believe in generalisability from one study.

Final conclusion (ctd.)

- In this view, generalisability means
  - similar questions are asked
  - with similar theory
  - with similar results
  - by (many) other researchers
- This is why literature search and writing a "state of the art" in a doctoral dissertation and relating this to own results is so important!