Content-specific research in science education

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Universität Bremen
Institut für Didaktik der Naturwissenschaften
Abt. Physikdidaktik

Hans Niedderer

Hans.Niedderer@mdh.se

http://www.idn.uni-bremen.de

MÄLARDALENS HÖGSKOLA
Institutionen för Matematik och Fysik

Overview

Four main perspectives

of science education research (SER):

1. Focus on content
2. Theory and practice
3. Some ideas about theory development
4. Visions for improving the teaching of science

1. Focus on content

Why focus on content?

- Learning is content specific
  (Seiler 1971)
- Learning is always the learning of something
  (Marton & Booth 1998)
- Content-oriented theories
  (Andersson & Wallin 2006)
- Pedagogical content knowledge - PCK
  (Shulman 1986; Loughran 2001)
- Content structure (“Sachstrucktur”)
  (Niedderer 1972; IPN curriculum physics; Duit & Brückmann 2008)

This means …

- Fachdidaktik
- Didactics of special subject areas
- Science education
- Content-oriented theory
- Domain-specific theory

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Andersson & Wallin 2006

”On Developing Content-oriented Theories Taking Biological Evolution as an Example”

” … for example, understanding conditions for learning of given topics under regular classroom conditions.”

”Some methodological problems … are discussed, as well as the role of content-oriented theories in strengthening science education research as an autonomous specialization within educational science”

Different type of theoretical contribution: ”How design work in general can be planned and carried out, and can be applied to different contents.”

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Lijnse (2000)

- ”What seems to be apparent from the literature is that science education research does not aim to develop content-specific didactical knowledge … but to contribute to … general educational and/or psychological theories. I consider this flight away from content detrimental ...”
- ”Through reflection on such practices, one might come to formulate content-specific theories regarding the teaching/learning of particular topics, … ”

Cobb, Comfrey, diSessa, Lehrer, and Schauble (2003)

”Domain-specific theories”

- ”**Design experiments** are conducted to develop theories, not merely to empirically tune “what works.” These theories are relatively humble in that they target domain-specific learning processes. […] A theory of this type would specify **successive patterns in students’ reasoning** together with the substantiated means by which the emergence of those successive patterns can be supported.”

Content-oriented theory

What means “theory”?

Generalisable empirical or theoretical results

Types of research for “content-oriented theory”

1. Determining content-specific objectives and relevant contexts
2. Students’ conceptions
3. Students learning pathways and learning processes
4. Developing content specific tests
5. Generalisable results about approaches
6. Determine content specific interest and motivation
7. Select those concepts, which are helpful/necessary to work with in relevant contexts, take away concepts that are not needed

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Content-specific SER, aspect 1: Determining objectives and relevant contexts

- “content-oriented norms”, ” Discussion about why the given area should be taught at school.” (A&W 2006)
- More research on context-based approaches (David Treagust)
  e.g. to determine relevant contexts
  - Noise pollution for teaching sound
  - Sustainable energy for teaching energy (Susanne Engström Lic 2008)
  - STS
- Asking experts
  e.g. Delphi method
  Several doctoral projects at FontD

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Content-specific SER, aspect 2: conceptions

- ”Old” areas with more and more theoretical results
- New theoretical background:
  - conceptual profile (Mortimer 1996); parallel conceptions (Hartmann & Niedderer, 2005);
  - cognitive tools (diSessa 1993; Stavy et al. 1998; Niedderer 2001)
- New areas
  - conceptions around chemical concepts like enthalpy (Tor Nilsson)
  - Conceptions related to STS contexts

Content-specific SER, aspect 3: Learning pathways and learning processes

- Driver 1989
- Duit, Goldberg & Niedderer 1992
- Scott 1987, 1991
- Petri 1996
- von Aufschnaiter & Welzel 1999
- Tasar, M. F. 2001
- Clement & Steinberg 2002
- Givry 2003
- Niedderer, Budde, Givry, Psillos, Tiberghien 2007
- Roger Andersson (ongoing doctoral project)

Content-specific SER, aspect 4: Developping content specific tests

- FCI Hestenes, Wells & Swackhamer (1992)
- …
- Thermodynamics test inventory TTI
  Einhaus & Schecker (2007)
- Systems thinking test (STT) Constantinide (2006)

Content-specific SER, aspect 5: Generalisable results about approaches

- “How can one deal with clashes between religious beliefs and scientific ideas about evolution?” (A&W 2006)
- General features in teaching a special content
- E.g. “electronium” approach in QAP
  Deylitz 1999
  Budde 2004

Content-specific SER, aspect 6:
Content specific interest and motivation

- "How can one get students to think actively and with interest about the various aspects of evolution?" (A&W 2006)
- Häußler (1980 – 2004)
- Materials science EU project (2007 – 2010)
  SDT, tests

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Content-specific SER, aspect 7: To determine those concepts …

- … which are helpful/necessary to work with in relevant contexts, take away concepts that are not needed
  - **Frequency** instead of **oscillation time** for noise pollution
  - **Efficiency, energy quality** and **exergy** for teaching sustainable energy

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Question

- **How do you classify the contributions of this Summerschool:**

  ( ) Working on content-specific theories
  ( ) Working on general pedagogical or psychological theories and apply them to a science content
  ( ) Some aspects of both

2. Theory and practice

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Aspects for theory and practice

- Our final aim is always to improve practice
- BUT: to some extend SER must develop its own theory and for that purpose be “off-practice”

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Theory and Practice – Example 1

- Cedric Linder and his group at Uppsala university
- Variation theory (Marton et al) used for improving science teaching at university level
  - Quantum physic
  - Chemical engineering
  - Several doctoral dissertations

Theory and Practice – Example 2

- Fred Goldberg and his group at San Diego State university
- Constructivist pedagogy used for improving science teaching at upper secondary level
  - Constructing physics understanding (CPU)
  - 12 units in mechanics, optics, heat and electric circuits with computer simulators for each (can be bought or using for free the simulators at internet)
  - 3 doctoral dissertations

Theory and Practice – Example 3

- Hans Niedderer and his group at Bremen university
- Students' conceptions and learning processes used for improving science teaching at upper secondary
  - Quantum atomic physic
  - 5 doctoral dissertations
  - Teaching material, both in German and English language, to be downloaded

Theory and Practice – Example 4

- Communicative approach (Scott)

	Interactive	Non-interactive
Focus on science view (Authoritative)	Presentation Q&A	Presentation ‘lecture’
Open to different points of view (Dialogic)	Probing Elaborating Supporting	Review

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3. Some ideas about theory development

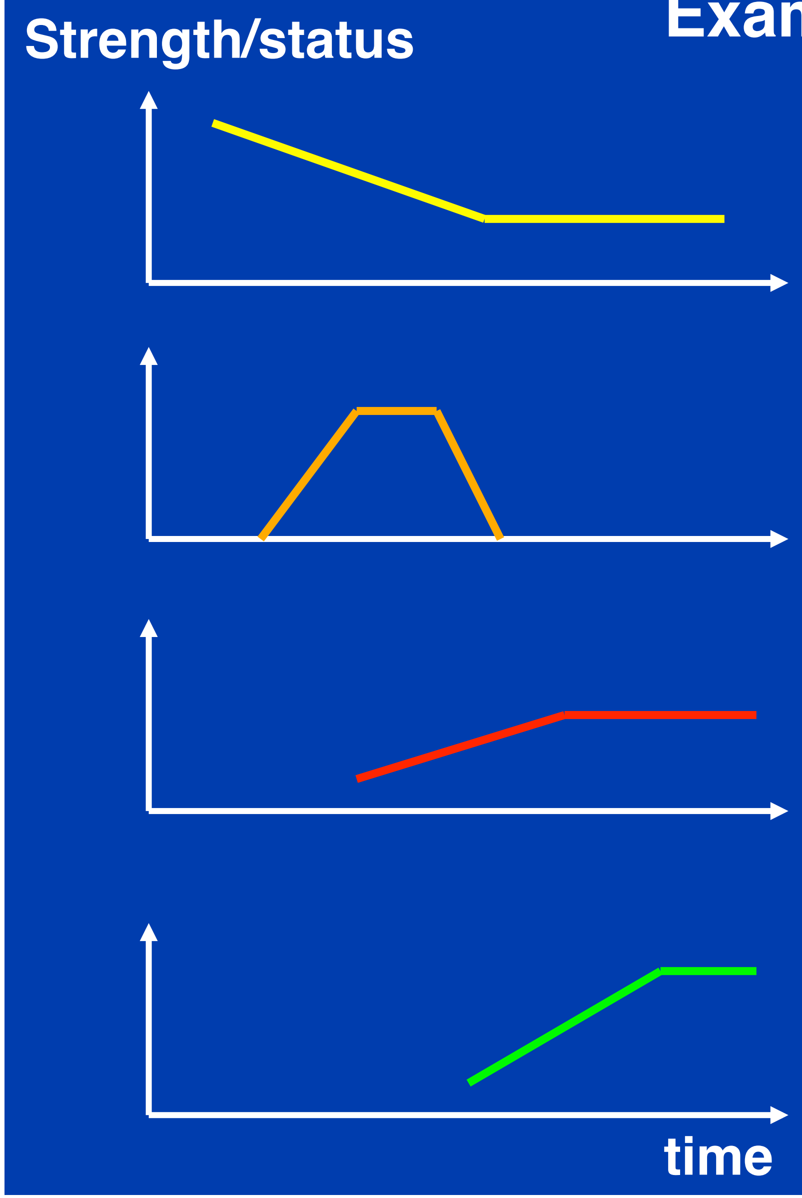
Some ideas about theory development 1

- **Students' conceptions 1:**
  Conceptual profile (Mortimer 1995)
  Parallel conceptions (Hartmann 2004)
- **Students' conceptions 2:**
  The idea of content specific cognitive tools ("cognitive atoms")
  (diSessa 1993; Stavy et al. 1998; Niedderer 2001)
- **Students' conceptions and conceptual change**
  - **types of learning (Tiberghien)**
  - **The idea of a triadic model (Strömdahl 2006)**
  - **Conceptual profile change (Mortimer 1996)**

An example of conceptual profile change

- A reconstruction based on data

Example: conceptions of an atom



Planetary conception

Smeared orbits conception

Quantum particle conception

Quantum cloud conception

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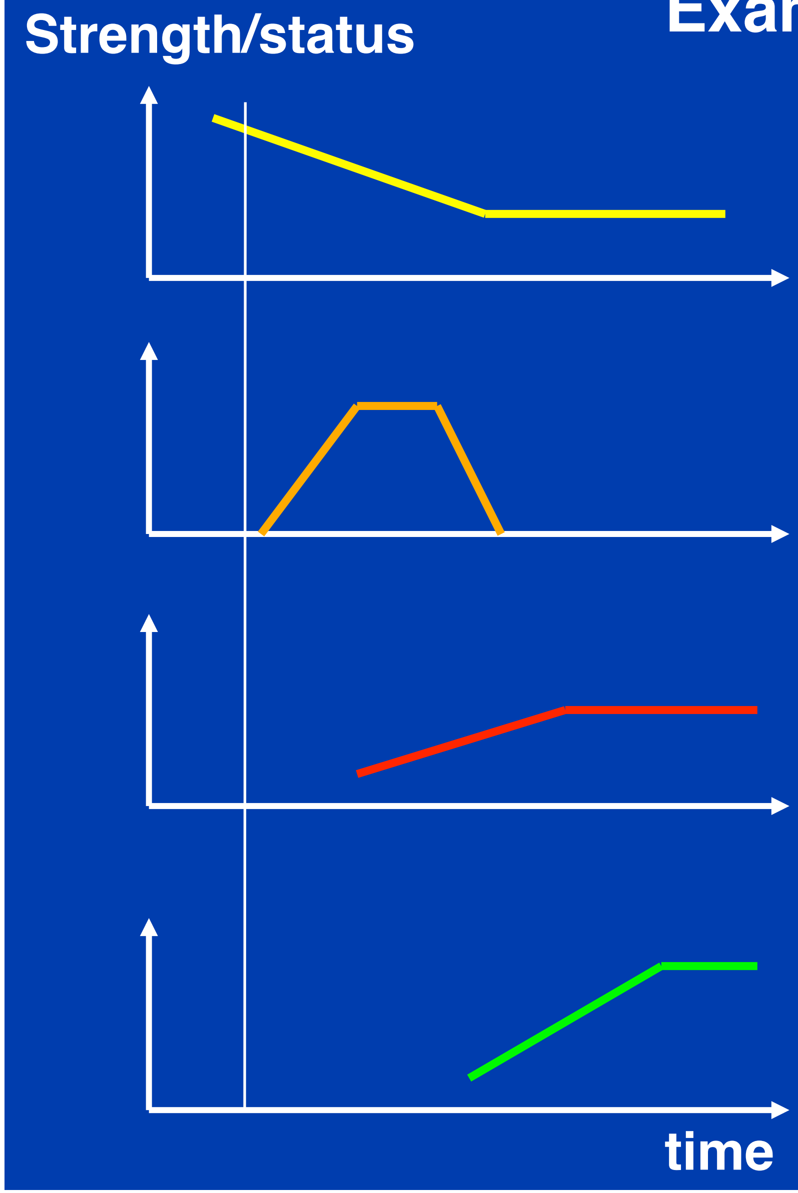

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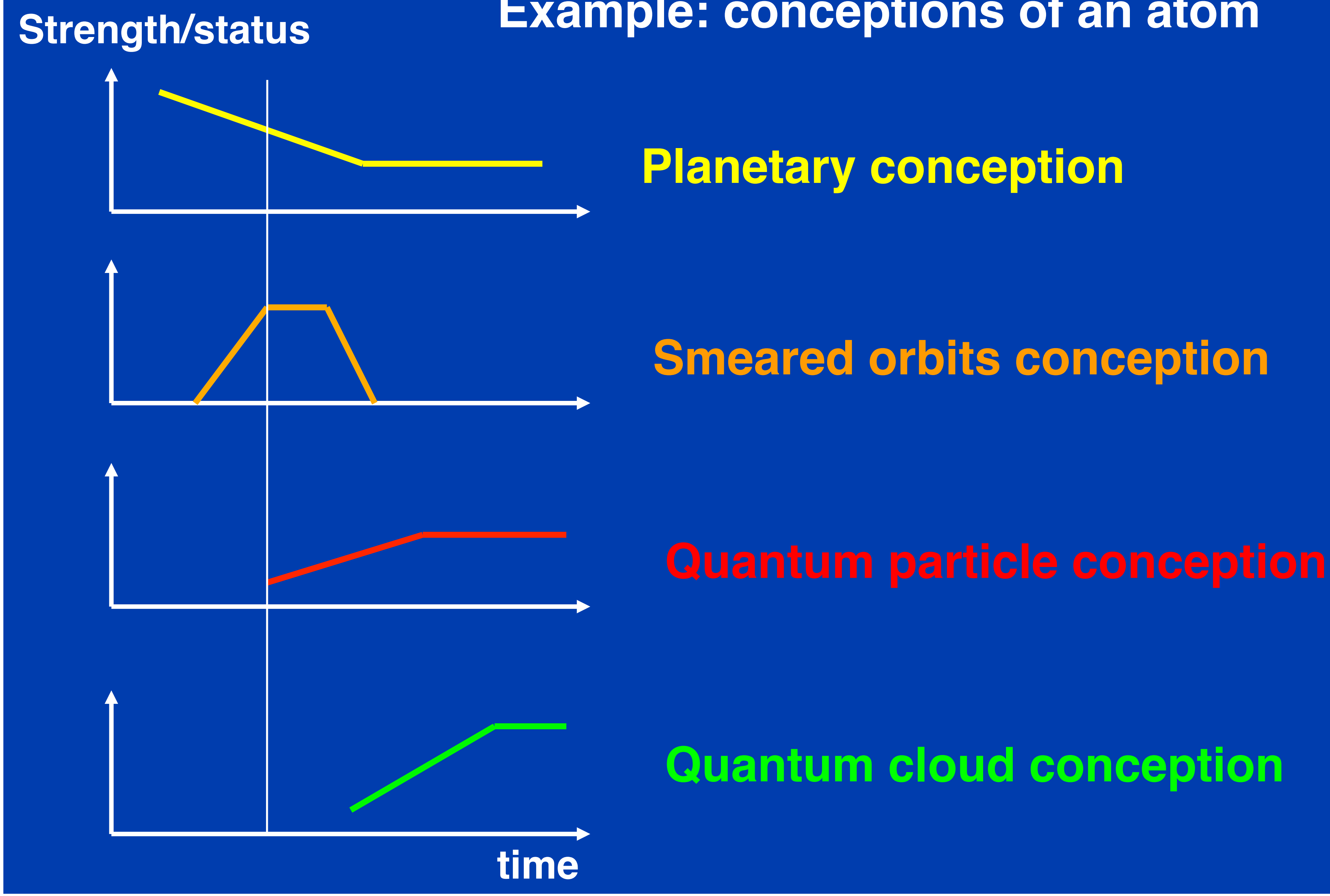

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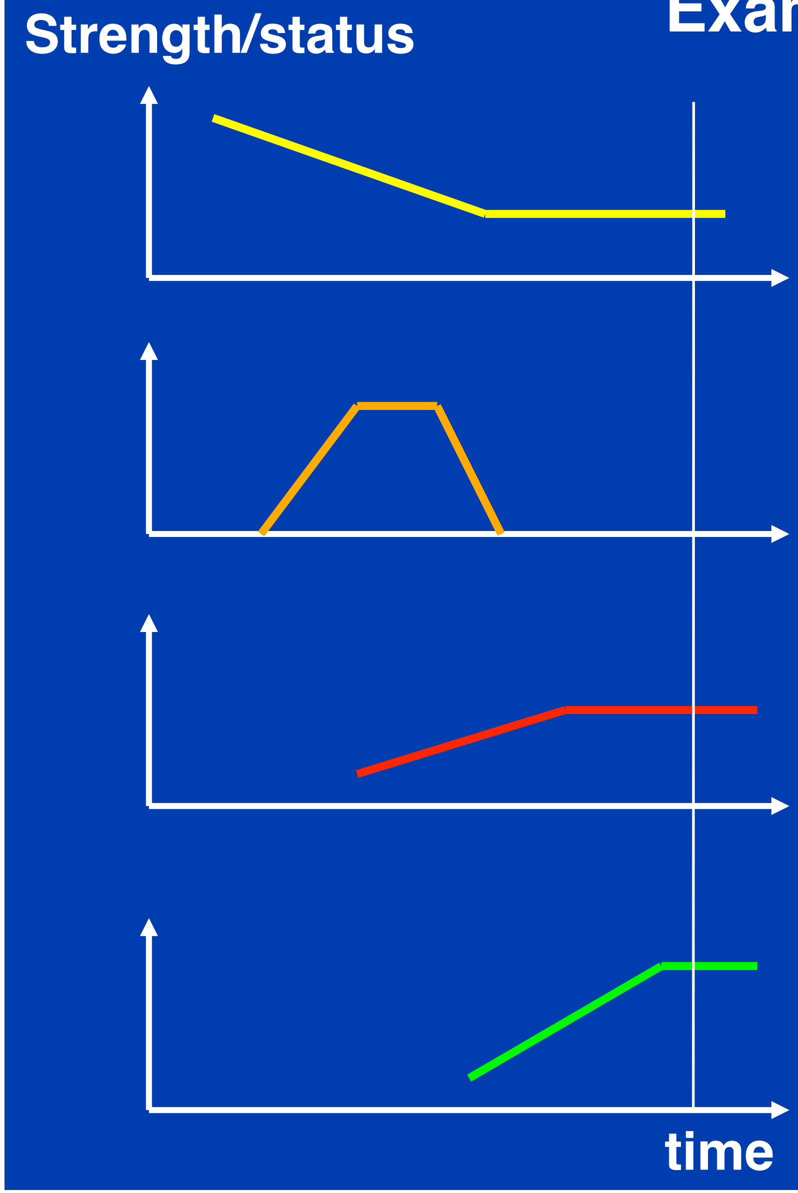

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Smeared orbits conception

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Some ideas about theory development 2

- **Learning pathways – learning process studies:**
  The idea to follow students' own constructions during learning for a specific content
  (Driver, Scott, Tiberghien, Clement, Niedderer …)
- **Impact of "inputs" on "learning":**
  The idea of content specific resonance
  (Glasersfeld 1991; Budde 2004)

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The idea of resonance (Glasersfeld 1991)

Learning environment

- teacher's statements
- other students' statements
- textbook

Learning effects

as resonance

Learning steps of a single student as conceptual evolution

Learning environment

Resonance

or

Non-resonance

Cognitive system of student

4. Visions
for improving the teaching of science

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Visions for school

- "Syllabus teaching" : "Project teaching" = 50:50

  Equal teaching time for
  teaching of basic concepts (according to syllabus)
  AND
  project learning with individual and social relevance

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Visions for better motivation in science teaching

- **Relevant new content/contexts** related to actual problems of individual and society (vision II of Roberts 2006)

- Group work with **ownership of learning** (Margareta Enghag 2007)

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Vision for teacher education

- PCK as main focus and content

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