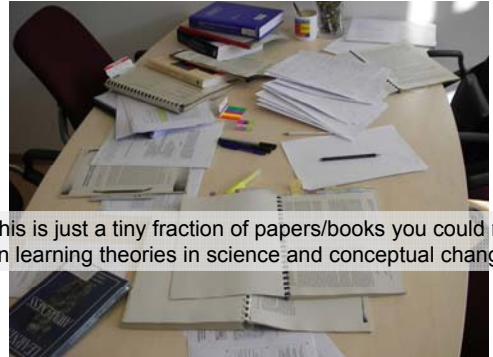


Conceptual Change in Science

Claudia v. Aufschnaiter & Christian Rogge
Justus Liebig University Giessen



Claudia's desk one week ahead of the Summerschool



This is just a tiny fraction of papers/books you could read on learning theories in science and conceptual change...



Aim of lecture:

„Readout-strategies“ (diSessa) rather than (detailed) information on theories, methods, and results.

Further reading – overviews

Duit, 1999; Duit & Treagust, 1998

Scott, Asoko, & Leach, 2007

Vosniadou, 2008a

Further reading – recently edited books/special issues

Vosniadou, 2008b

Cultural Studies of Science Education, 2008, 3(2)

Limón & Mason, 2002

Sinatra & Pintrich, 2002



Some theoretical approaches to conceptual change

Posner et al.: “classical conceptual change approach”

Vosniadou et al.: framework-theory-approach

Chi et al.: ontological categories

diSessa et al.: p-prims and coordination classes

[Marton et al.: ways of experiencing]

(diSessa, 1993; diSessa & Sherin, 1998; diSessa, 2002; Chi, 2008; Marton & Booth, 1997, chapters 5 & 6; Posner et al., 1982; Strike & Posner, 1992; Vosniadou & Brewer, 1992)

→ Focus of most approaches: Describe and explain learning difficulties (in science)

→ None with expanded/explicit focus on emotions, motivation, interest etc. (e.g., Pintrich, Marx, & Boyle, 1993; Tyson et al., 1997)



Outline

Part I: Setting the scene...

Part II: What are concepts?

Part III: Considering and investigating conceptual change

Part IV: Promoting conceptual change

Part V: Take home messages?



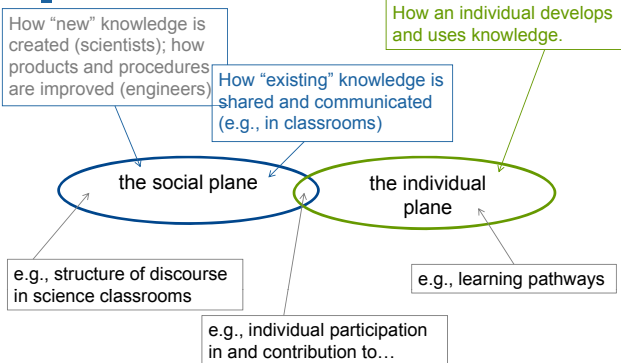
Relevance of conceptual change theory?

Issues of conceptual change are closely related to science learning:

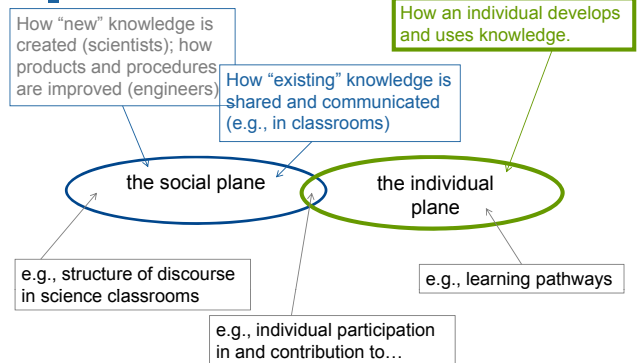
- Students' knowledge of scientific concepts, of the nature of science, of experimental activity, of argument, ...
 - Teachers' beliefs about the teaching and learning of science
 - Students' and/or teachers' behaviour and its relationship to their knowledge
 - Promoting students' learning processes/developing teaching material/teacher education
- What “are” the concepts of an individual / a group about...
→ How are concepts employed into activity?
→ How do concepts change and how can change be promoted?



Social or individual (very (!) briefly, more in e.g. Scott et al., 2007)



Social or individual (very (!) briefly, more in e.g. Scott et al., 2007)



Outline

Part I: Setting the scene...

Readout-strategies I:

- Is your research associated with conceptual change research? In what way?
- Does your research focus on a more individual or a more social perspective or a bit of both?



Outline

Part I: Setting the scene...

Part II: What are concepts?

Part III: Considering and investigating conceptual change

Part IV: Promoting conceptual change

Part V: Take home messages?



A 2-minutes "workout"

- 1) Write down one or two concepts relevant to your field (you might focus on students' conceptions).

There are lots of words out there:

Knowledge, belief, theory, concept, conception, ...

- 2) If you can, think about a "definition" of what you **would count as a concept** and the criteria with which you would identify a concept (as distinct from other types of verbally expressed knowledge).
[Why are your examples in 1) concepts/conceptions?]



The nature of concepts...

"There is no doubt that we need a better understanding of what concepts are and how they change with development and learning. Researchers usually avoid dealing directly with the question of what concepts are, although many [...] would adopt the historicist view of concepts as changing and evolving and as embedded in larger theoretical frameworks from which they derive their meaning."

(Vosniadou, 2008a, p. xvi)



The nature of concepts...

"There is no doubt that we need a better understanding of what concepts are and how they change with development and learning. Researchers usually avoid dealing directly with the question of what concepts are, although many [...] would adopt the historicist view of concepts as changing and evolving and as embedded in larger theoretical frameworks from which they derive their meaning."

(Vosniadou, 2008a, p. xvi)

"a concept has several perceptible features and conceptual attributes, and a concept can be viewed as belonging to some category. For example, a *robin* has a red breast (a perceptible feature), lives in temperate climate (more of a conceptual attribute), and belongs to the category of *birds*."

(Chi, 2008, p. 62)



Which ones "are" concepts/conceptions?

"*This is my baby-chair*" (*my mum told me that*)

All chairs have an area to sit on and four legs.

Yesterday, cycling was quite hard, we had a lot of wind.

The heavier the resistance (e.g., wind), the more force is needed to cycle at steady speed.



Which ones "are" concepts/conceptions?

"*This is my baby-chair*" (*my mum told me that*)

Yesterday, cycling was quite hard, we had a lot of wind.

→ Knowing a "label" for a **specific** object.

→ **Reporting an experience** you've (just) made.

All chairs have an area to sit on and four legs.

The heavier the resistance (e.g., wind), the more force is needed to cycle at steady speed.

→ Expressing a **generalization** for a class of situations, objects, or events.



Which ones "are" concepts/conceptions?

Phil Scott's lecture on Wednesday:

"A common sense theory of motion/falling:

- *If an object is supported it does not fall;*
- *If not supported it falls until once more supported;*
- *Falling has an initial cause, namely the loss of support; [...]"*

→ Expressing a **generalization** for a class of situations, objects, or events.



Conceptual knowledge

No matter, which word/label is used, at least implicitly, **conceptual knowledge** is often referred to as:

A) "implicit or explicit understanding of the principles that govern a domain" (Rittle-Johnson et al., 2001, p. 341)

B1) being part of "larger theoretical frameworks" or belonging to categories (e.g., Chi, Posner, Vosniadou)

B2) being a complex interrelated set (diSessa)

(for a critical discussion of what counts as a concept: diSessa & Sherin, 1998, pp. 1155-1170)



Your examples?

Do your written down concepts have the status of some "generalization" over a class or situations, events, objects?
How about your "definition" of what you would count being a concept?

If conceptual knowledge refers to the principles that govern a domain there must (also) be knowledge which is not (yet) conceptual.



Side note I: Concepts and conceptions

Concepts: Scientific knowledge
[“correct”, not under dispute?]

Phil: scientific concepts

Conceptions*: Students’ knowledge of the scientific concepts
[“incorrect”, needs to be developed]

Phil: spontaneous concepts

(Dillon, 2008, p. 399 referring to Wells and Treagust & Duit in the same issue)

→ Likewise for concepts, clear “definitions” for *conceptions* usually lack.

? How about scientific knowledge which currently develops or is under debate? Are these “scientists’ conceptions”? How do we know when these become “concepts”?

*sometimes: Students’ (conceptual) knowledge including emotional factors

One concept?

“the misconception ‘there is no motion without force’ should be replaced with the expert belief ‘there is no acceleration without force’. [...] this is a change in the *relations* among the concepts that appear in these beliefs. [...] concepts such as force, motion, and acceleration [...]”

(diSessa & Sherin, 1998, p. 1156 with reference to Carey, 1988)

One concept?

“the misconception ‘there is no motion without force’ should be replaced with the expert belief ‘there is no acceleration without force’. [...] this is a change in the *relations* among the concepts that appear in these beliefs. [...] concepts such as force, motion, and acceleration [...]”

(diSessa & Sherin, 1998, p. 1156 with reference to Carey, 1988)

? What is “one” concept?

word by word (just nouns?), sentence by sentence (every sentence or just a few?), larger units of speech (how long? when does the “next” concept start? how do we know?)

→ Notion of **grain size**:

- a) elements and their interrelationship
- b) context-specificity versus “breadth”

Grain size [a) interrelated elements; b) “breadth”]

small → **broad**

- a) diSessa: p-prims – causal nets – coordination classes
 - a) Chi: belief – mental model – ontological category
 - a) Posner: concepts – conceptual ecology
 - [a) Marton: element of a phenomenon – structural aspect of a phenomenon]
 - b) Vosniadou: mental model – belief (part of specific theory) – presuppositions (part of framework theory)
- Usually, the smaller particles constitute the broader “net”
 - The broader net “controls” which particles are activated *but* external (“social”) factors have an influence as well

Where “is” conceptual knowledge “located”?

Concepts as mental entities (frameworks/categories):

Focus on what is “behind” students’ situated activity (what “produces” this (verbal) activity)

(e.g., Chi et al.; Vosniadou et al.; diSessa et al. (partly); Posner et al.; ...)

Framework-theory-approach (Vosniadou et al.)

mental entities

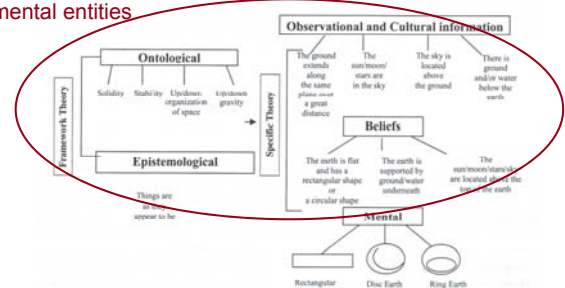


FIGURE 1.2 Hypothetical conceptual structure underlying children’s mental models of the earth. (Vosniadou, Vamvakoussi & Skopeliti, 2008, p. 8)

Where “is” conceptual knowledge “located”?

Concepts as mental entities (frameworks/categories):
Focus on what is “behind” students’ situated activity (what “produces” this (verbal) activity)
(e.g., Chi et al.; Vosniadou et al.; diSessa et al. (partly); Posner et al.; ...)

Concepts as generated ways to experience the world:
Focus on utterances and activities which are presented
(e.g., diSessa et al. (stressing that this needs to be taken into account); Marton et al.; v. Aufschnaiter, 2006a/b)

? These are (*the*) two different “paradigms” of conceptual change research? (“mental entity” vs. “situated activity”)

Conceptual knowledge?

“This is my baby-chair” (my mum told me that)
Yesterday, cycling was quite hard, we had a lot of wind.
→ Knowing a “label” for a **specific** object.
→ **Reporting an experience** you’ve (just) made.

ontological category *entities*
(branch *objects-artifacts-furniture-chairs*)
(Chi, 2008)

ontological category *processes*
(branch *direct*) (Chi, 2008)

Ohm’s p-prim: An agent that is the locus of an impetus that acts against a resistance to produce some sort of result (diSessa, 1993)

Some arguments against a “mentalistic view”

- Self-reports of conceptual understanding of teaching and learning are inconsistent with activity (research on teacher belief and classroom practice)
 - For a number of activities it is obvious that conceptual knowledge does not “produce” this activity (e.g., physics knowledge for keeping the balance while you cycle?)
 - Architecture of the brain:
“neural nets reactivated and recomposed in-line via selection; not a place or body of description of how the world or agent’s behavior appears” (Clancey, 1993, p. 111)
“compatibility between the [...] hardware of the brain [...] and the theories of learning” (Roth, 1998, p. 1022)
- Don’t misinterpret “no conceptual knowledge stored in the brain to control activity” with “there is nothing in the brain”!

Outline

Part I: Setting the scene...

Part II: What are concepts?

Readout-strategies II:

- What is counted as conceptual knowledge? (Is there any knowledge considered which is “less” than a concept?)
- What are the “grain sizes” of conceptual knowledge?
- How “near” or “far” is conceptual knowledge from observable activity?

Outline

Part I: Setting the scene...

Part II: What are concepts?

Part III: Considering and investigating conceptual change

Part IV: Promoting conceptual change

Part V: Take home messages?

Identifying change requires identifying concepts

“I could tell you that I’m right-handed. If you didn’t already know that then I’ve just added to your knowledge, if, and only if, you believe me. [...] If I now tell you I’m actually left-handed then, you have to choose whether or not to believe this new piece of knowledge. If you accept it as true then you’ve just undergone a brief moment of cognitive conflict and undergone conceptual change.” (Dillon, 2008, p. 400)

? Where “is” the conceptual knowledge “in” there?

? What is supposed to change?

Justin is always a trustful person → Justin is always a liar

All people have a preferred hand → [remains the same]

Justin usually uses his right hand → ... his left hand

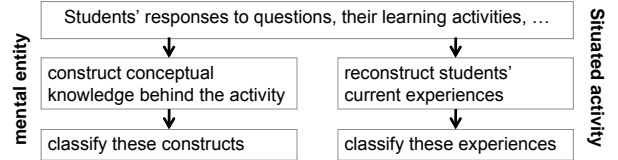
Why Justin's example is not typical

- i) Conceptual change research focuses on conceptions which can be contrasted with the scientific point of view
 - ii) Conceptual change is investigated in situations which aim at promoting the learning of (a) scientific concept(s)
- Conceptual change researchers might stress that this example is "just" about knowledge acquisition and, thus, not very "interesting"

! **Conceptual change addresses "fundamental reorganizations of the knowledgebase"**
(Vosniadou, 2008, p. xvi)



Approaches to conceptual change



- Interviews and questionnaires are very common
- tracing (a group of) individuals in classroom situations or teaching experiments is often used for learning process studies (Niedderer, lecture at the Summerschool 2006)
- **All approaches use categories for classification** – either content specific (e.g., Vosniadou) or structural (e.g., Chi)



Side note II: 1st or 2nd order perspective

1st order perspective on conceptual knowledge:
What do I (analyst) think has "caused" my (the student's) behaviour? What is the phenomenon at which I look?

→ Interpretation from one's own perspective (including judgement such as "correct" or "incorrect")

2nd order perspective on conceptual knowledge:
How does this person perceive the situation? How does this person understand what she/he is doing/saying?

→ Trying to seeing the world through someone else's eyes.

(Marton & Booth, 1997; Marton & Pang, 2008, p. 535)



Side note II: 1st or 2nd order perspective

'there is no motion without force'

1st order: Student has an incorrect concept: For steady speed the resulting force is zero (expert's knowledge)

2nd order: This is the student's experience: Whenever the student wants to move an object (in this world) at steady speed she/he has to exert a force.

→ Typically, cc-research uses only a 1st order perspective

! A 1st order perspective is in more risk to "overestimate" what learners (!) think while acting (confusing what an expert can think of with the learner's understanding)

! A 2nd order perspective is important for the construction of learning material...



Changing from naïve to scientific concepts

Changes are usually described in terms of "from naïve to scientific" (sometimes including intermediate states)

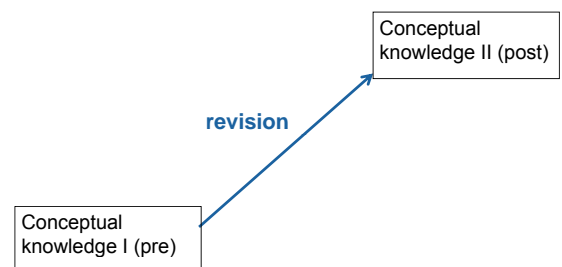
? Are there any other opportunities to describe increasing quality in students' understanding?
(e.g., *levels of complexity* as proposed by Welzel, Fischer, v. Aufschnaiter; the "*speed*" with which conceptual knowledge is developed and applied; ...)

"Exchange" between the old and the new conception is usually not happening

→ Conceptual status: preference of one concept over the other (summary in Duit et al., 2008, pp. 631-632)



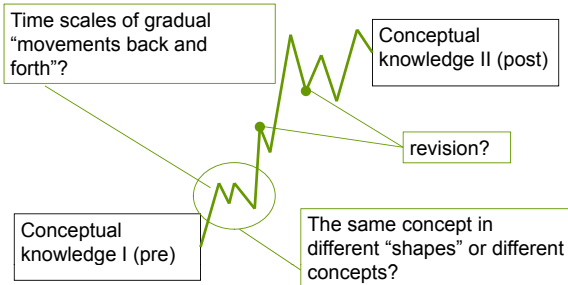
Side note III: Revision or enrichment?



(Duit, 1999, p. 263)



Side note III: Revision or enrichment



Side note III: Revision or enrichment

Conceptual change is assumed to be a gradual and slow process (e.g., Vosniadou, 2008, p. xvi) but...

- Research on conceptual change often has a rather “static” focus: typically, “changes” are considered over hours, weeks or months [“learning outcomes”]
- How gradual and how slow the process is, i.e. how often in minutes conceptualizations might change, is rarely explicitly investigated (and would need a 2nd order perspective)
- How and when the *social plane* (learning opportunities) contributes to the *individual plane* is typically not explored in conceptual change research

Why is conceptual change so hard to achieve?

Some mental entities are very stable

- A) The **development** of cross-linked mental entities is generally difficult (diSessa)
 - B) Specific **changes** in the networks or the way elements are integrated/connected are difficult (the bigger the grain size the more difficult)
- B) cannot describe why *new* conceptual knowledge is difficult for students
- A) cannot describe why *contradictory* conceptual knowledge is difficult for students

Outline

Readout-strategies III:

- How is conceptual knowledge and its change determined from empirical data? (Which criteria are used to identify conceptual knowledge and its change?)

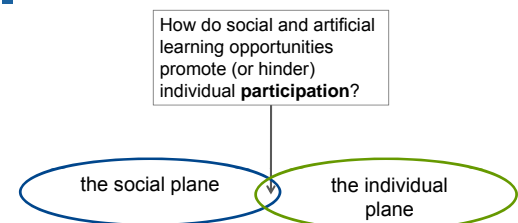
Part III: Considering and investigating conceptual change

- Are the data appropriate to evidence the conclusions? (E.g., pre-post-tests or (short) interviews are not appropriate to infer slow and gradual learning processes)

Outline

- Part I: Setting the scene...
- Part II: What are concepts?
- Part III: Considering and investigating conceptual change
- Part IV: Promoting conceptual change**
- Part V: Take home messages?

The interrelationship between social and individual



When and why are ants more interesting?

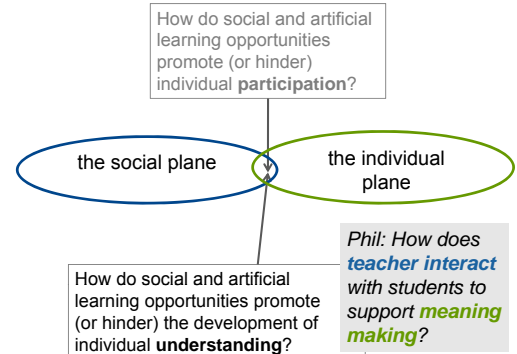
Teacher: Come on then Josie, let's see what's she's got to say. Remember to face your audience Josie and tell them as you're doing it. **Nathan!** Have you got ants in your pants?



Example taken from Phil's lecture



The interrelationship between social and individual



Conceptual Change – typical assumption

- “Posner criteria” (Posner et al., 1982; Strike & Posner, 1992)
- Students need to be dissatisfied with their existing conceptions
- A new concept must be intelligible to students
- The new concept must be plausible
- The new concept helps a learner to solve problems (fruitful)



Video-example from Peter's lecture

- T: Water has a skin which takes care that the water stays together.
- P: (shakes head) [no]



Conceptual Change – typical assumption

- “Posner criteria” (Posner et al., 1982; Strike & Posner, 1992)
- Students need to be dissatisfied with their existing conceptions
- A new concept must be intelligible to students**
- The new concept must be plausible
- The new concept helps a learner to solve problems (fruitful)

- ? How do we know that any “offered” concept (information, explanation) is likely to be intelligible/plausible at a specific stage of the learning process? — 2nd order perspective!
- ? How do we know how to “introduce” a concept so that it can be understood “conceptually” (not just as a means to describe a particular phenomenon)?
- ? How do we know about the time scales of these processes?



Robin's lecture: Science ed. research as compared to...

...taking pills:

If this is the progression of an illness, which treatment is best at which stage?

- Knowledge of the *development* of an illness is very important for finding appropriate medicine.
- *Testing* medicine is not just taking pills and then coming back for a check in two weeks time.



Developing instruction

Meheut's slides: Need to take into account "scientific concepts and the competencies to be developed by the students"

Knowledge about students' conceptions and the scientific concepts necessary but not sufficient for the development of instruction!

→ How do students *establish* an understanding of scientific concepts?

Promoting conceptual development requires instruction which matches students' *situated* understanding.

→ Criteria are needed to describe individual knowledge *and* learning requirements (in order to detect the "size" of the ZPD or the level of appropriate learning demand)
(v. Aufschnaiter & v. Aufschnaiter, 2003; v. Aufschnaiter, 2003)



Side note IV: Misconceptions or missing experiences?

'there is no motion without force'

→ The student has no experience or not enough experiences with movements without friction and (thus) does not focus on other forces acting on the moving object
[2nd order perspective]

Is this a misconception which needs to be **changed** or do we need to **expand on students' experiences** with movements?

→ Extensive rather than "demonstrative" experiments (i.e., series of experiments)

→ Knowledge about "misconceptions" important to plan experiences students need to make in order to develop different/new conceptual knowledge
(e.g., v. Aufschnaiter, 2006a; v. Aufschnaiter & v. Aufschnaiter, 2007)



Intervention based on CC – many open questions!

Social plane



Personal plane



Picture from Phil's lecture

Internalisation with restructuring

Composition of classroom interaction and group work?

How long does this process take?

Which kind of instruction and when in the learning process?

Ratio between "introduction" and "practice"?

... !



Outline

Readout-strategies IV:

- Are there any criteria presented which are used to describe both students' prior conceptions (knowledge) and the level of learning demand? (not just misconceptions vs. scientific)
- Are there any assumptions about how to take learning processes into account for the development of instruction?

Part IV: Promoting conceptual change

Part V: Take home messages?



Outline

Part I: Setting the scene...

Part II: What are concepts?

Part III: Considering and investigating conceptual change

Part IV: Promoting conceptual change

Part V: Take home messages?



Take home messages I: State of research

- Over the last about 30 years conceptual change research has achieved detailed knowledge about students' conceptions in several areas (predominantly in physics)
- As research is mainly based on pre-post-testing or interviews, we (still) lack detailed knowledge about the *gradual, slow processes* of conceptual *development*
- So far, conceptual change research shares some (tacit) agreements such as regarding concepts as mental entities but overall, frameworks are different and there is an ongoing debate



Take home messages II: From readout-strategies to

“research strategies”:

- What is your assumption about what you would count as conceptual knowledge (and what not)?
- How do you identify “a” concept from the research products you are using? Be clear about the criteria and procedures!
- Obviously, the learning of science concepts is influenced by several factors. Within a dissertation, you cannot investigate all factors/theoretical assumptions which are mentioned!
Which parameters are you addressing and which ones are you leaving out?



How about Peter?

Conceptual *change*,
conceptual *enrichment*, or
conceptually *confused*?



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Appendix

Chi's categories

These categories are not seen as being set forever, rather, new or other categories might emerge whereas others are removed. (drawing from Chi, 2008, p.64)

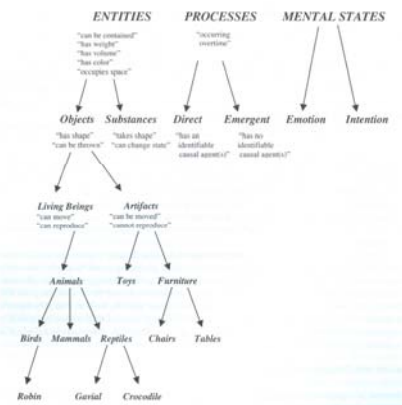


FIGURE 3.1 Distinct ontological trees: hierarchical and lateral categories within a tree and between trees.



Clancey, 1993, p. 111

Immediate behavior:

[...] always new; always a sensorimotor circuit

Representation:

Created and interpreted in our activity [...];
external representation ≠
representing to self ≠
neural structures

Memory:

neural nets reactivated and recomposed in-line via selection;
not a place or body of description of how the world or agent's
behavior appears



Theoretical arguments against a mentalistic view

“doing a task intelligently means being guided by internally represented declarative knowledge about the task. But then the use of internally represented knowledge must be guided by declarative knowledge about *what* knowledge to use, *how* to use it, and so on. The use of that declarative knowledge has to be guided by declarative knowledge on a higher level. Again, there is no end: This is Ryle's regress.”

(Marton & Booth, 1997, p. 10)



What does a conceptual change approach to learning need?

- 1) Assumptions and descriptions about *how* prior conceptions (conceptual knowledge) have (has) evolved
Prior experiences which were then abstracted are often stressed (e.g., Duit, 1999, p. 267)
 - 2) A description of how conceptual knowledge is changed (if it “is” already “existing”, otherwise see 1)
Enrichment and revision
 - 3) A description of how new or revised conceptual knowledge is “stabilized”
e.g., *conceptual status* (e.g. Duit, 2008, pp. 631-632)
- A detailed outline on how knowledge about processes as described in 1) to 3) can be used to inform instruction (current models only focus on the conceptions students *have* but not on their learning)



Identifying change requires identifying concepts

“I could tell you that I'm right-handed. If you didn't already know that then I've just added to your knowledge, if, and only if, you believe me. [...] If I now tell you I'm actually left-handed then, you have to choose whether or not to believe this new piece of knowledge. If you accept it as true then you've just undergone a brief moment of cognitive conflict and undergone conceptual change.” (Dillon, 2008, p. 400)

How would Michele Chi, Andrea diSessa, Peter Hewson, Ference Marton, Stella Vosniadou, ... interpret this example?

→ In order to understand better advantages and limitations of as well as challenges to theoretical frameworks, it would be great to get these (and other) researchers to outline their methodological and theoretical approach at identical examples.

