Communicative interaction for acquiring conceptual systems knowledge

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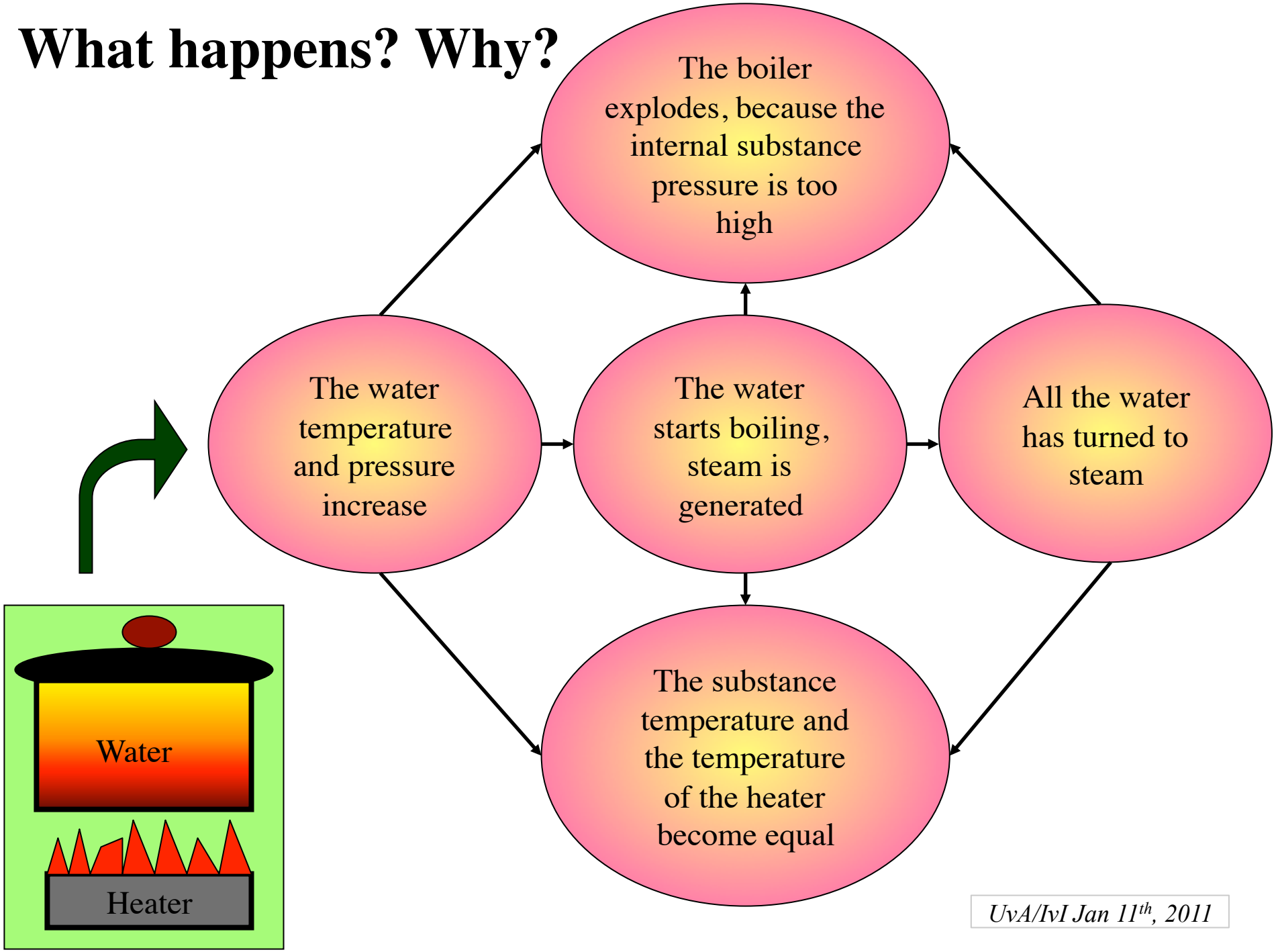
Overview

- **Problem statement and Context**
- Knowledge representation and Reasoning
- Progressive learning spaces
- Feedback for Reflective thought
  - Semantic Web techniques (model ingredients)
  - Consistency-based Diagnosis (simulation results)
- Inducing Motivation
- Concluding remarks

What happens? Why?



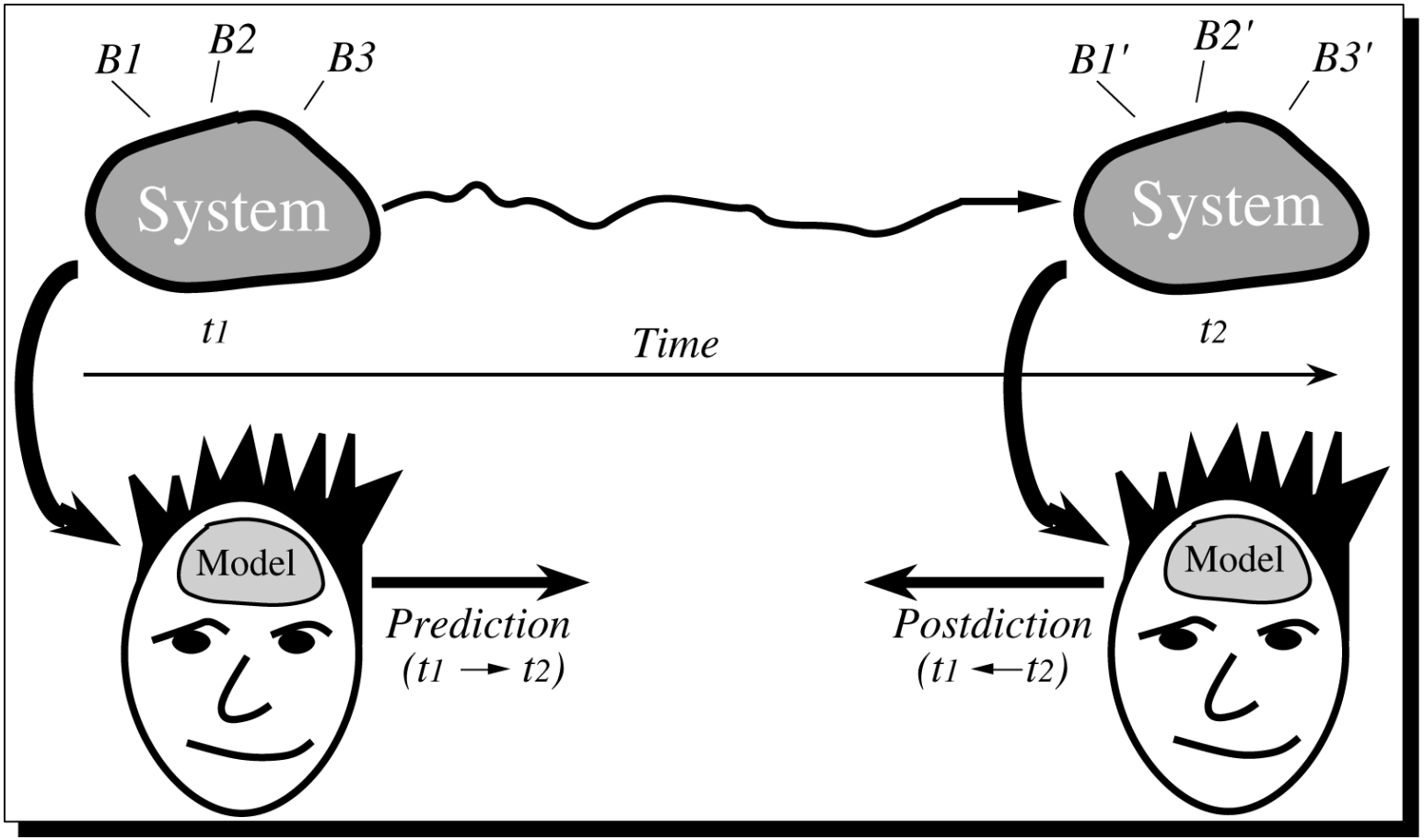
The Princeton Review AP Environmental Science Test

2007

32. Which of the following organisms is the first to be adversely affected by thermal pollution in a stream?

(A) Trees along the bank
(B) Insect larvae in the water
(C) Large fish migrating up stream
(D) Birds drinking the water
(E) Bacteria in the water

Envisioning (Mental simulation)



Context and Relevance

Qualitative System Dynamics

- Having learners acquiring *conceptual* knowledge of system's behaviour.
  - Important for society to successfully interact with its environment.
  - Being able to adequately explain and predict the behaviour of systems to utilise their functioning for human benefit.
  - A prerequisite for working with numerical models and equations.
- Hence, policymakers and other stakeholders strive to accomplish effective science education.

What does it entail?

- System selection
  - Identify entities (and structure)
  - What is relevant/irrelevant?
  - Structure versus behaviour
- Determining Processes (incl. start/stop)
- Quantities
  - Causal relationships
  - Critical landmarks
  - Qualitative distinct behaviours
- Assumptions / Perspectives
- *Etc.*

Artificial Intelligence & Education:

Mettes and Roossink, 1981;
Kleer and Brown, 1984;
Elio and Sharf, 1990;
Ploetzner and Spada, 1998;
Schumacher and Gentner, 1988;
Frederiksen and White, 2002;
Forbus and Feltovich, 2001;
Schwarz and White, 2005;
etc…

DynaLearn - Main objective

- To develop an interactive learning environment that allows learners to construct their *conceptual* system knowledge.

Learners

Workspace for interactive knowledge constructing

Feedback generators:
- Semantic technology
- Model diagnosis

Reflective interaction with virtual characters

DynaLearn

- Applied to (environmental) science education
- Secondary & Higher education

Communicative Interaction

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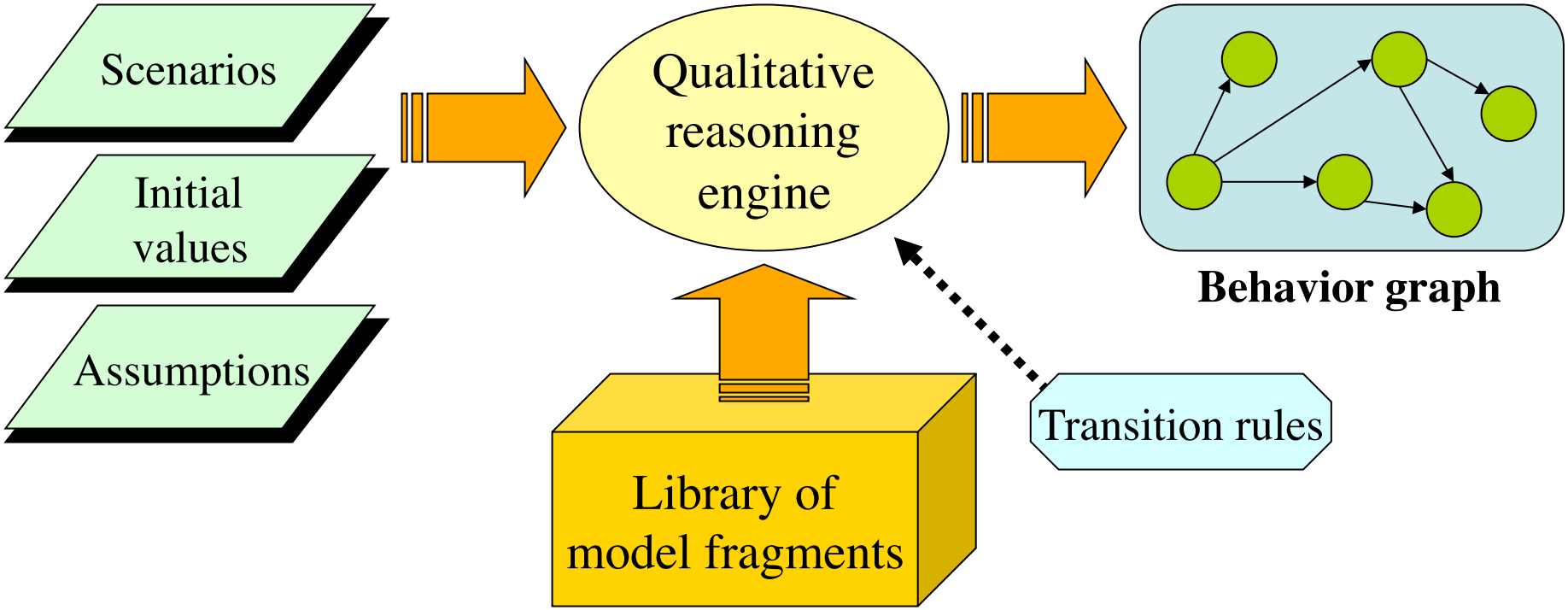
Qualitative Reasoning Engine

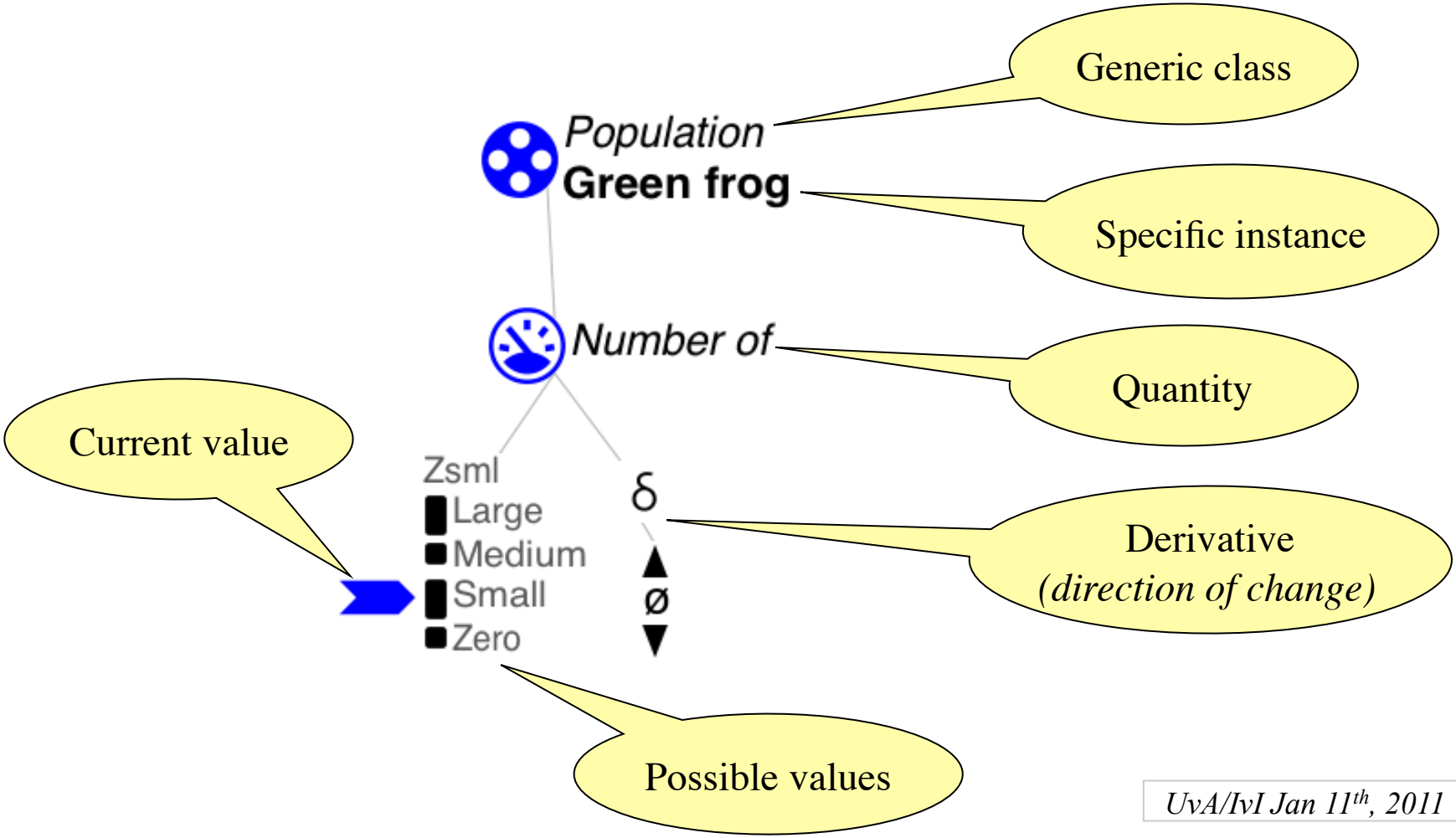


Example: Population dynamics

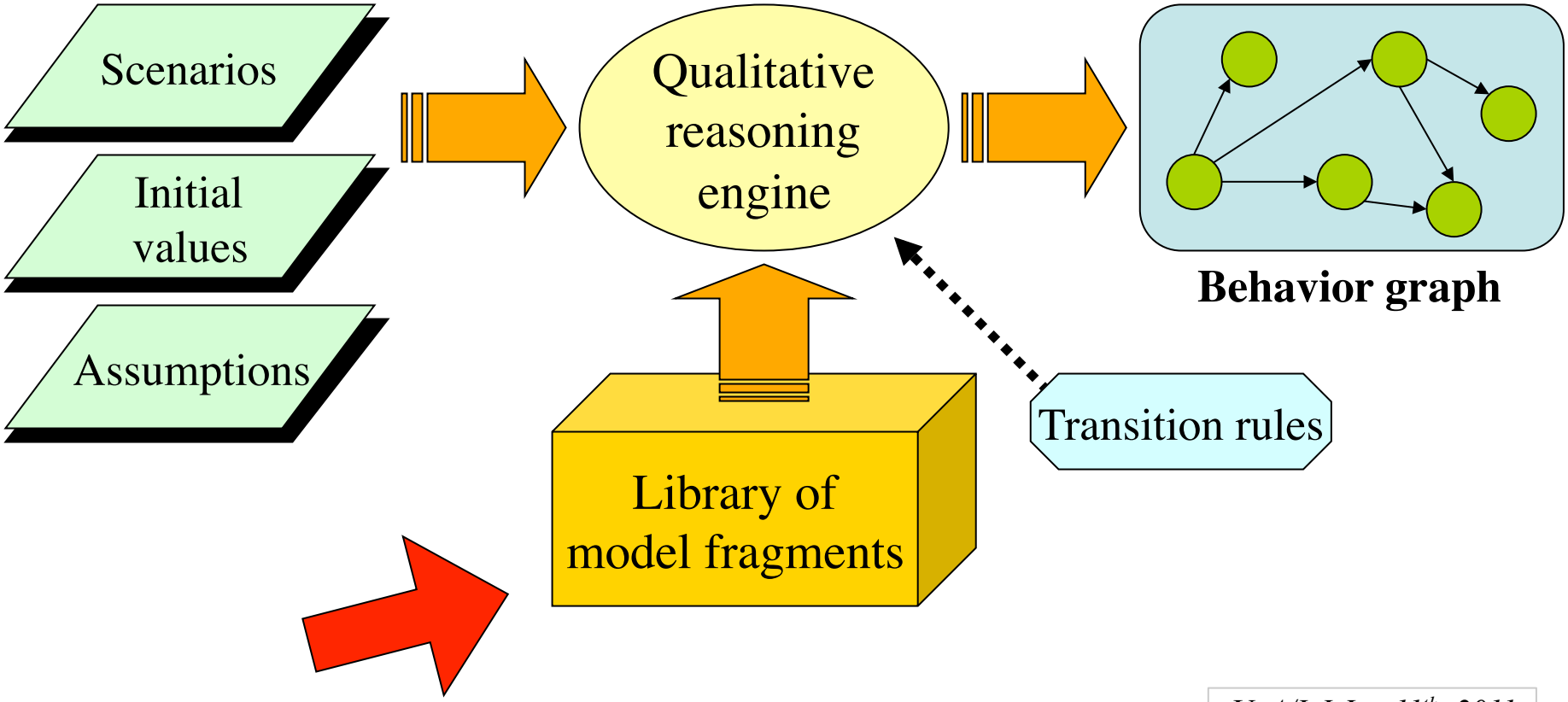
- How do populations in general behave?
- What processes determine their behaviour?

- *Issues:*
  - Size *(number of individuals)*
  - Birth / Natality
  - Death / Mortality

Scenario *(Starting situation)*



Qualitative Reasoning Engine

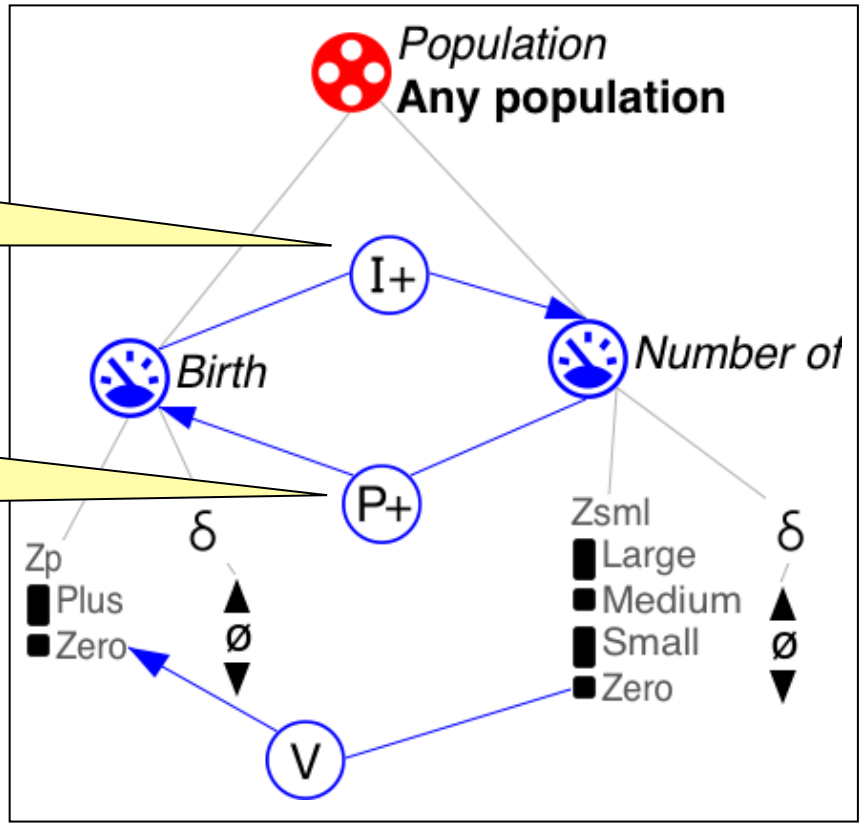


Red: Condition
Blue: Consequence

Capturing partial knowledge

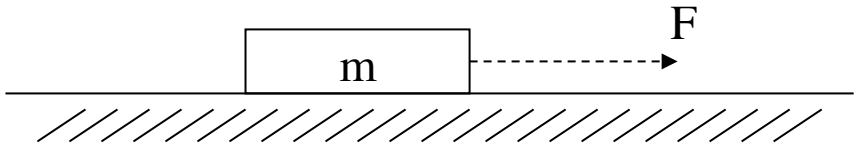
Influence:
The amount of Birth increases Number of

Proportionality:
Changes in Number of determine changes in Birth



Mathematical foundation

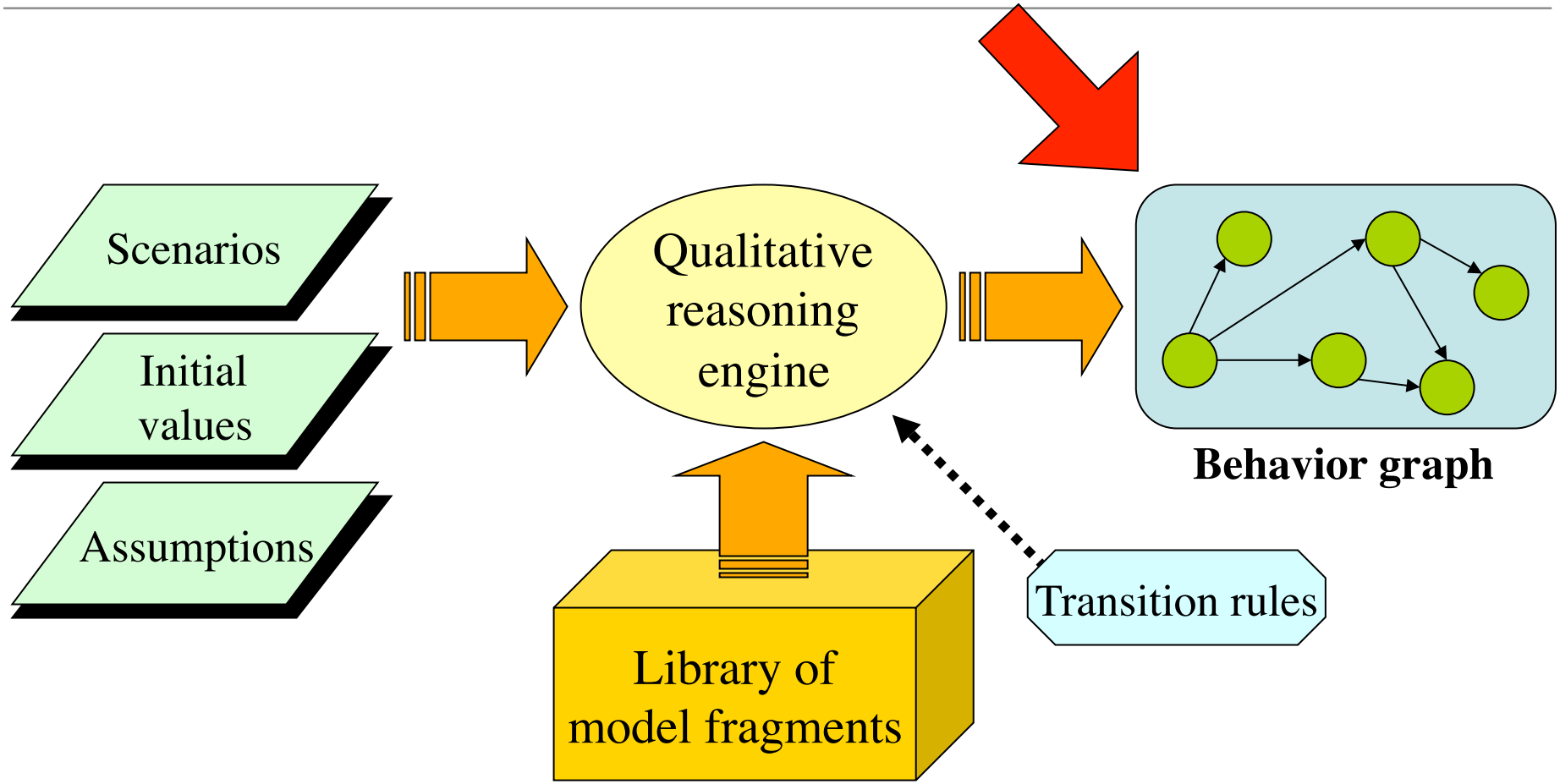
Causality → Directedness



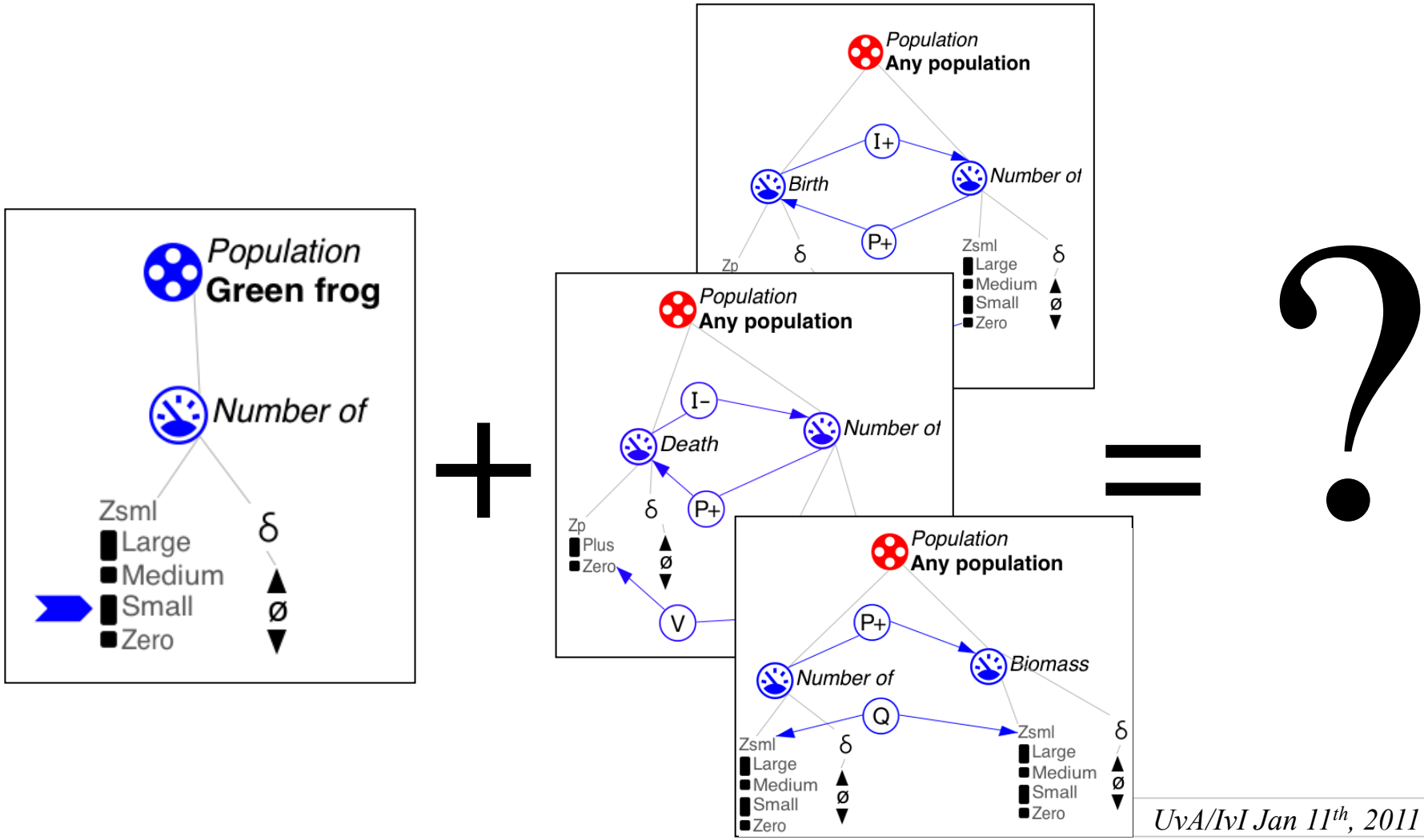
F = m * a

- We say that:
  - An increase (or decrease) in Force causes an increase (or decrease) in Acceleration
  - An increase (or decrease) in Mass causes an decrease (or increase) in Acceleration
- But we do not say:
  - An increase in Acceleration causes …

Qualitative Reasoning Engine

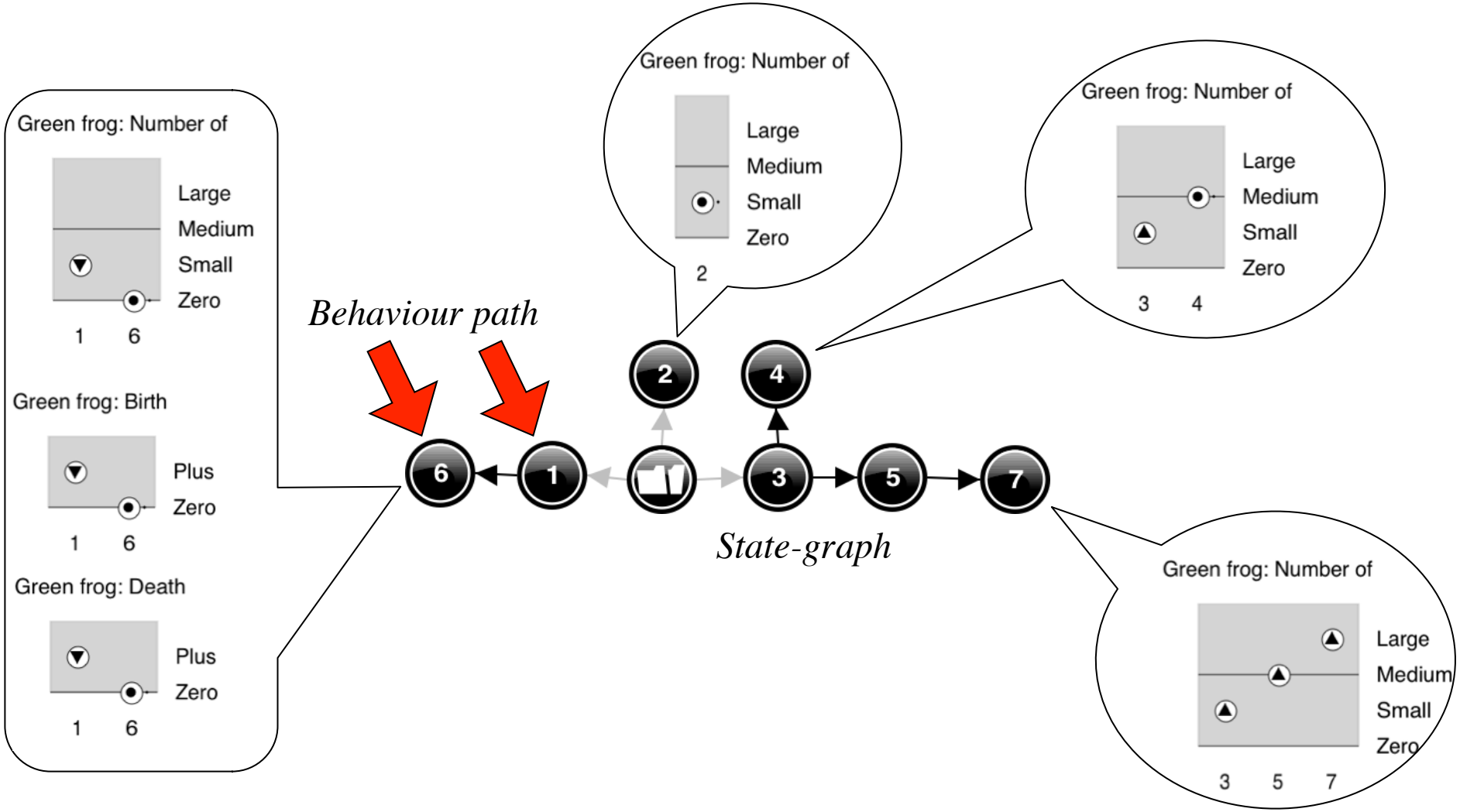


Simulation


Population
Green frog
Number of
Zsml
Large
Medium
Small
Zero
δ
+
Population
Any population
I+
Birth
Number of
P+
Zp
δ
Zsml
Large
Medium
Small
Zero
δ
Population
Any population
I-
Death
Number of
P+
Zp
Plus
Zero
δ
V
Population
Any population
P+
Number of
Biomass
Q
Zsml
Large
Medium
Small
Zero
δ
Zsml
Large
Medium
Small
Zero
δ
=
?

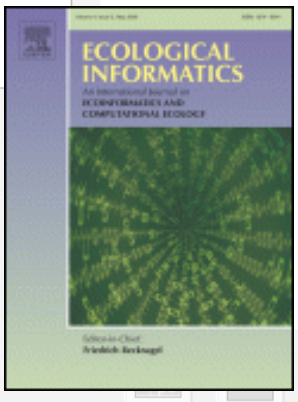
Simulation results

State-graph & Behaviour Paths



NaturNet-Redime

http://www.garp3.org



Special issue:
Ecological informatics, 4(5-6), 2009

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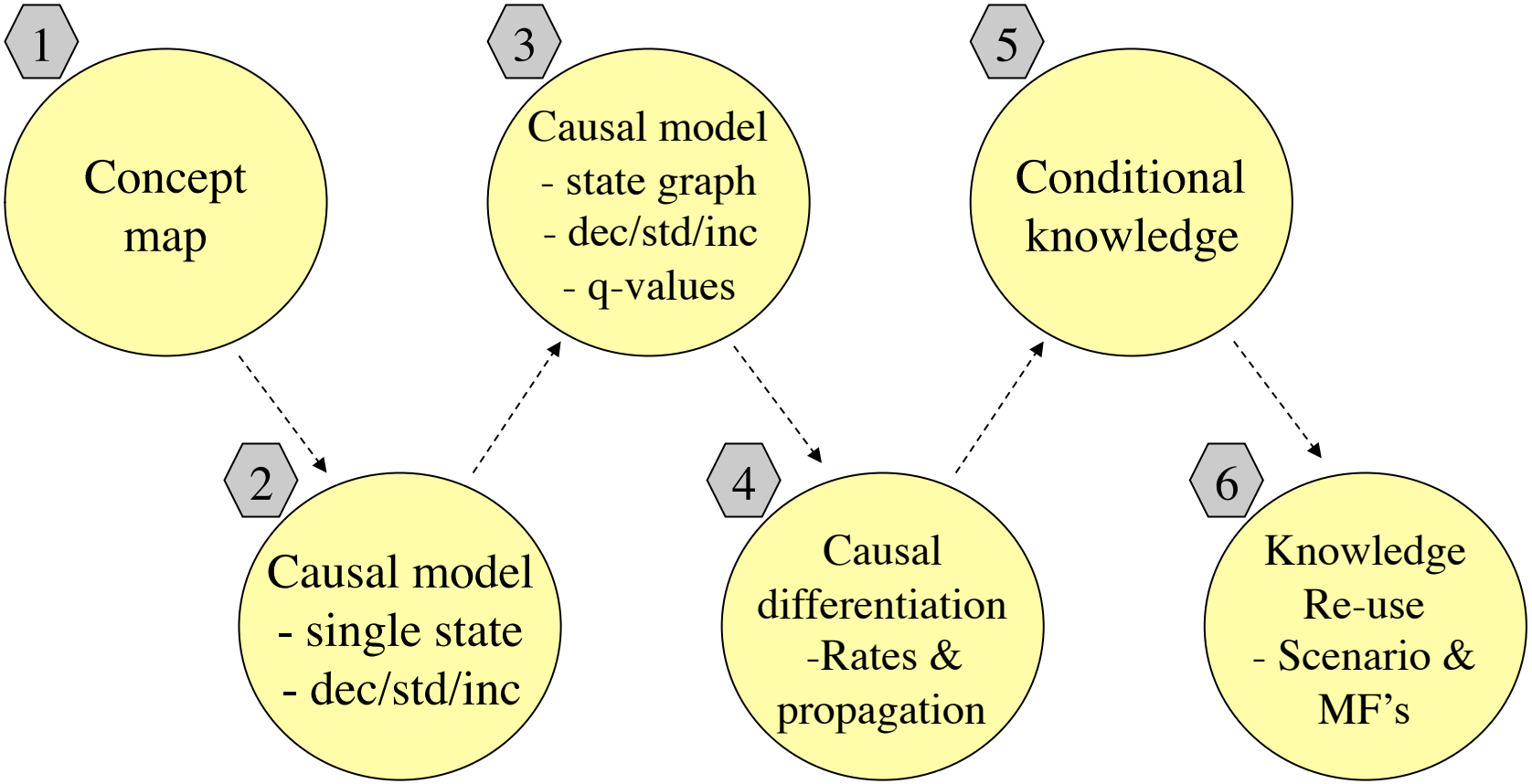
Representation scaffolds

- Acquiring conceptual knowledge of system behaviour is difficult
  - How to support learners in discovering and constructing this knowledge?
- Idea/Approach → Learning spaces
  - Create a set of progressive workspaces for learners to work through.
  - Each space with specific knowledge representation & reasoning features relevant to system behaviour.

Requirements and Support

- Learning space: *requirements*
  - Be logically self-contained (to allow simulation).
  - Highlight unique and relevant aspects.
- Learning space: *support delivered*
  - *Focus* + *Consistency*: a restricted set of primitives at each level to construct knowledge.
  - *Reflection*: simulation provides learners an instrument for reflecting upon their understanding.

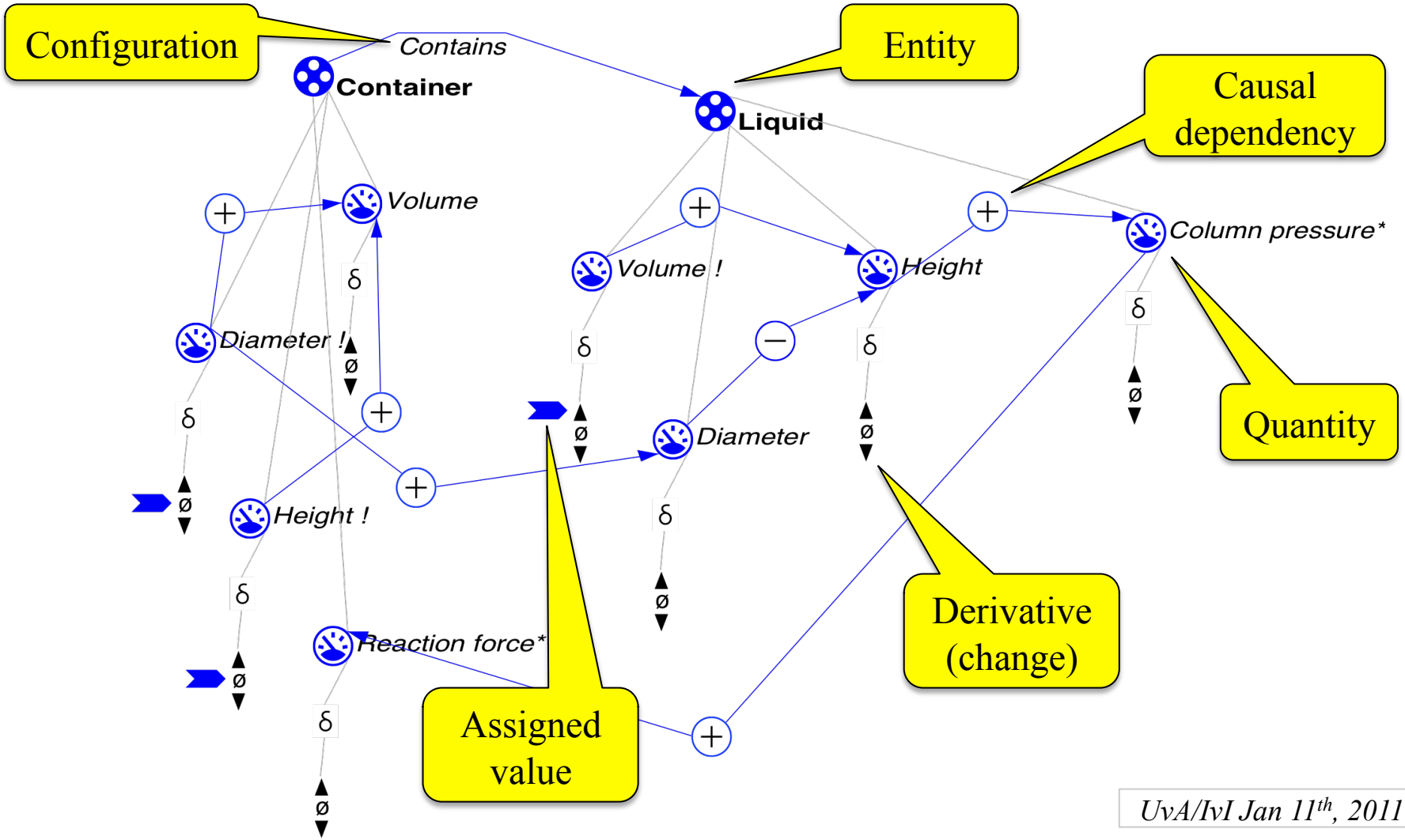
Progression of Learning Spaces



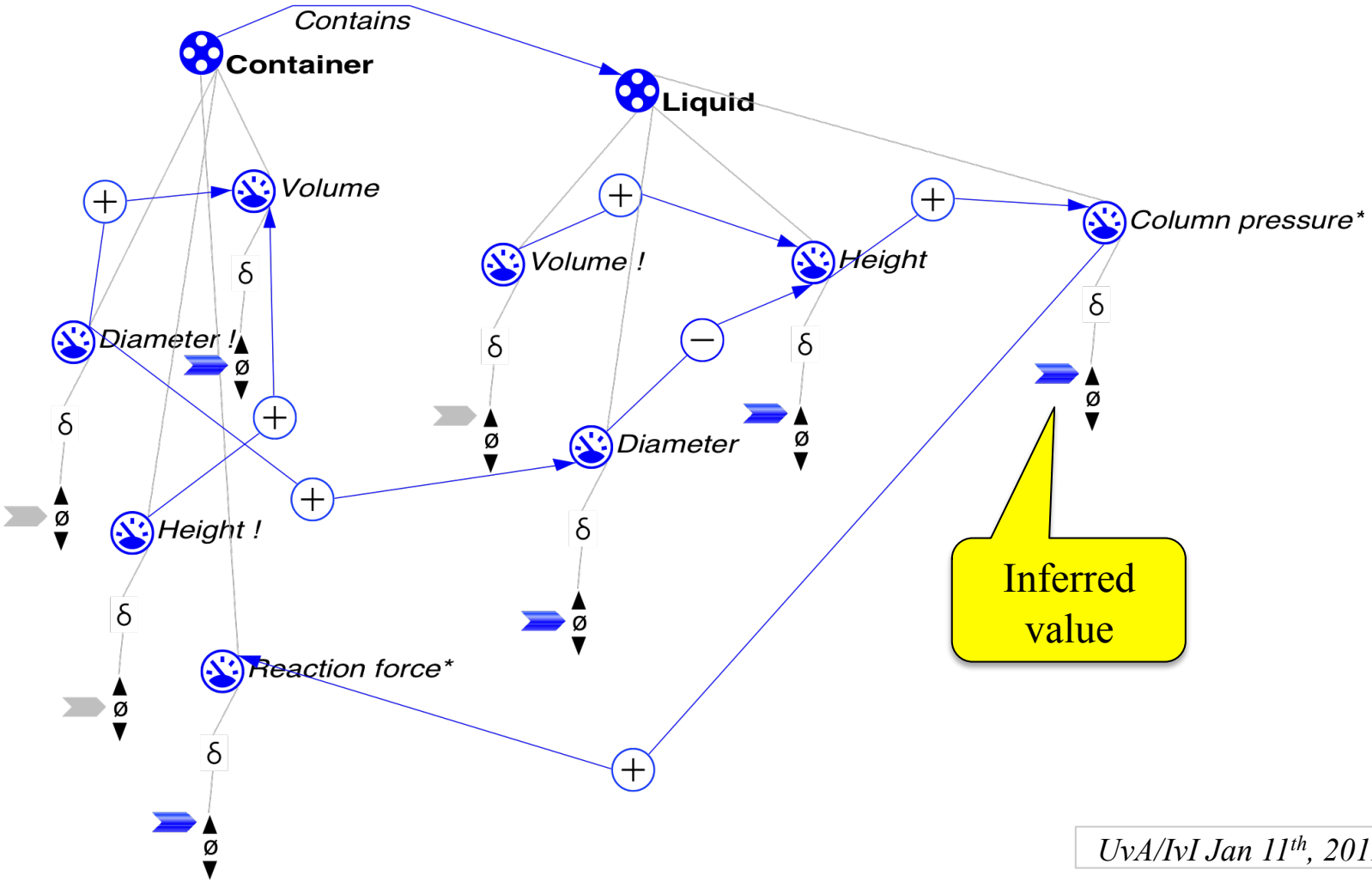
Learning spaces

1. *Concept map*
   - Which concepts are involved and how are they related?
2. *Basic causal model*
   - What constitutes the system (structure vs. behaviour)?
   - How do changes propagate through the system?
3. *Causal model with state graph*
   - Which quantities may reach critical landmarks? What are these landmarks?
4. *Causal differentiation*
   - What is the (initial) cause of change? How are changes propagated?
   - What processes are involved? What external 'agents' are involved?
5. *Conditional knowledge*
   - Are their behaviours that only occur under specific conditions?
6. *Generic and reusable*
   - System independent descriptions facilitating simulation of scenarios with an 'arbitrary' set of system features

LS2 - Causal model (Building)



LS2 - Causal model (Simulating)



What is discovered at LS2?

- Entity / Quantity distinction
  - Important improvement over concept maps!
- Causal dependencies (→ overall causal model)
  - Between which quantities?
  - Positive / negative?
- Ambiguity
- Inconsistency
- *Extra:* Also available as Teachable agent mode

Bredeweg et al., 2010 (EC-TEL, LNCS 6383)

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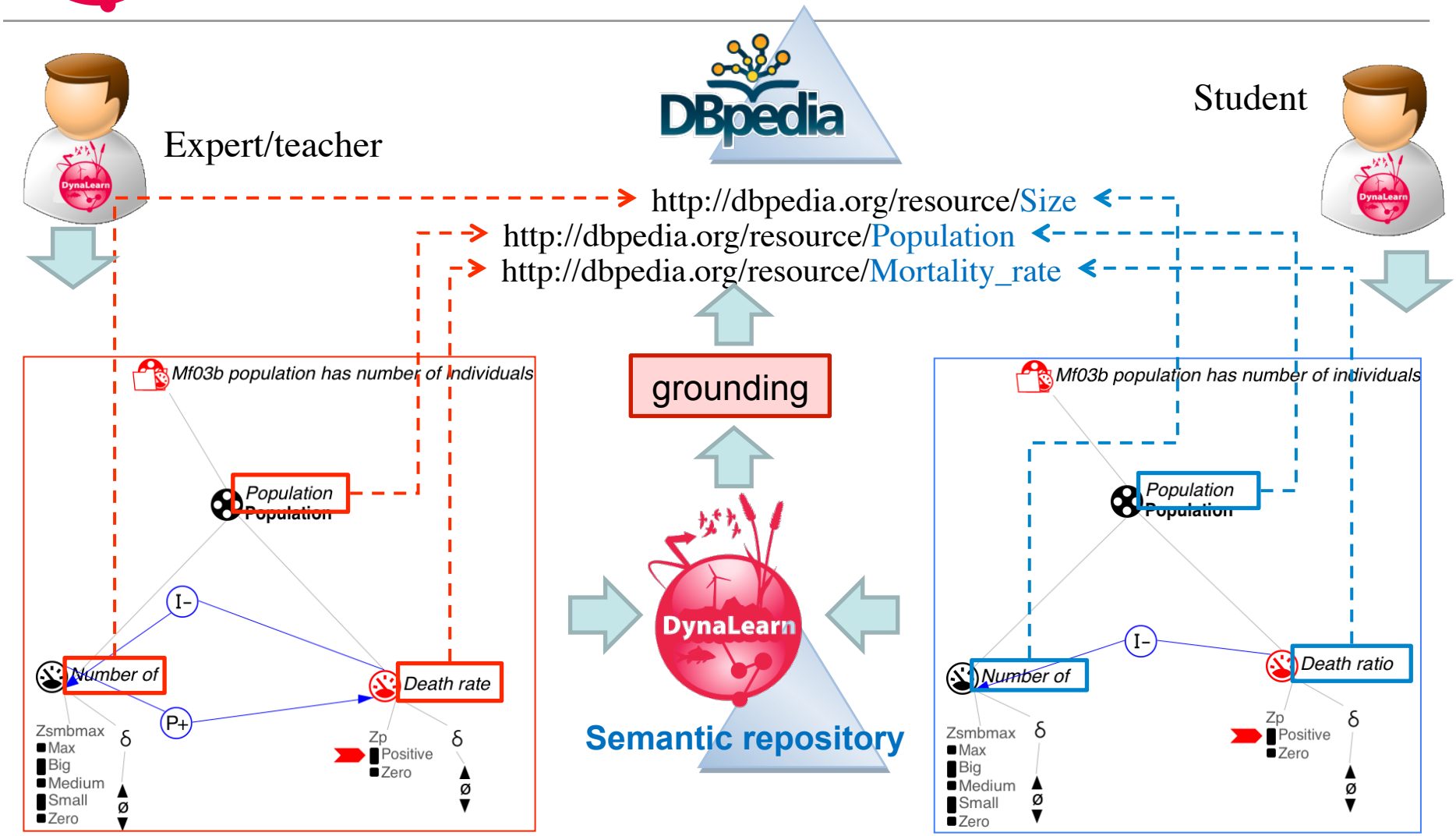
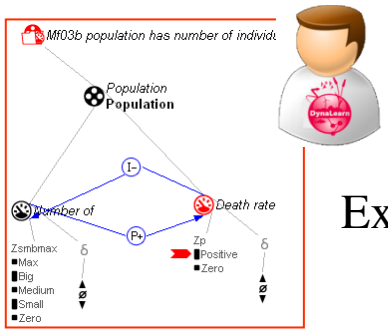
Generating feedback



Generating feedback

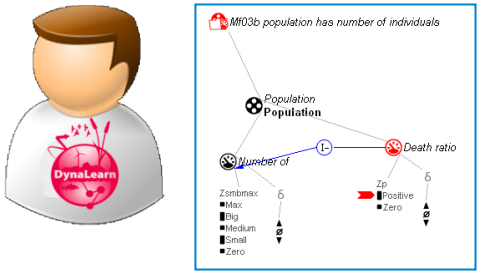
e.g., "You can complete your model with a P+ proportionality"

feedback

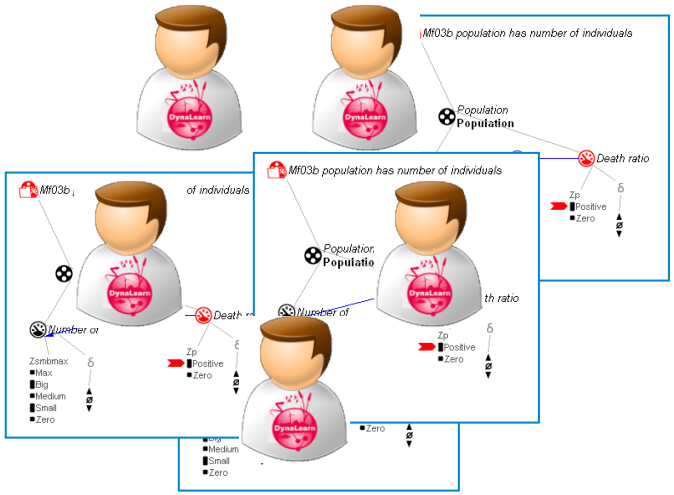


Expert

Student



Community of users



e.g., "Users who modelled death also modelled birth"

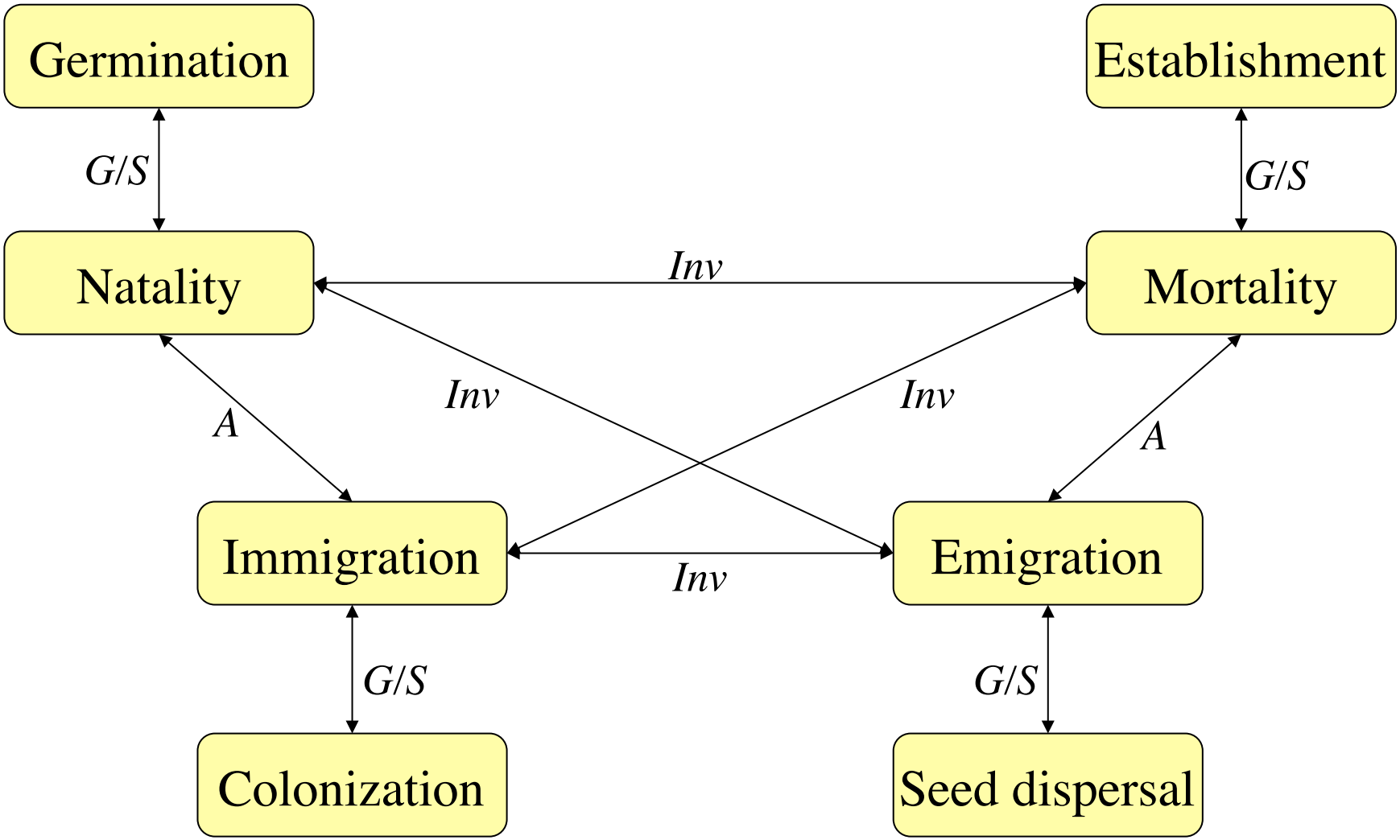
recommendations

Matching - *by* Dimension

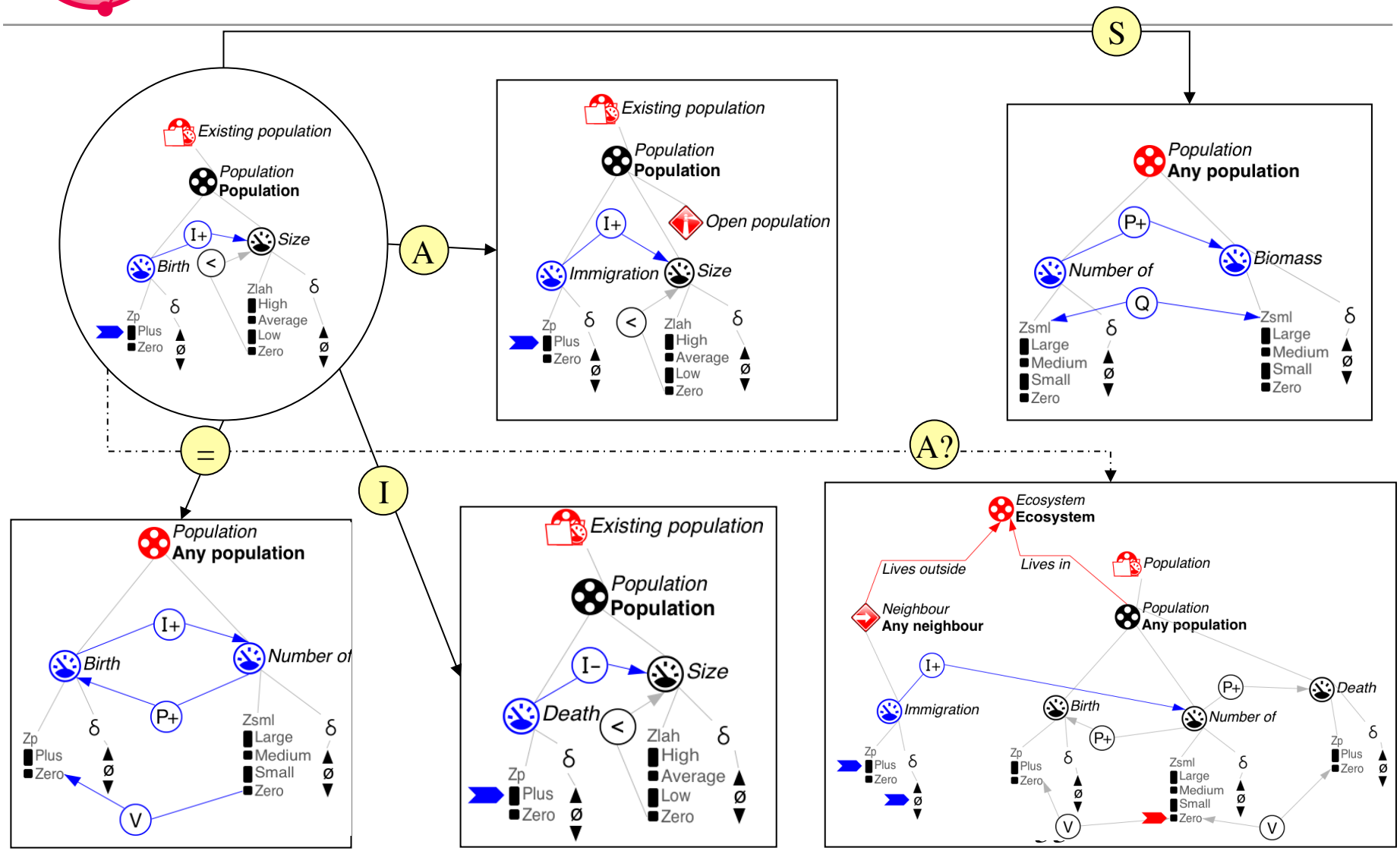
- Generalisation / Specialisation (G/S)
- Analogy (A)
- Inverse (I)
- Order (O)
- Structural change (SC)

- Equal (=)

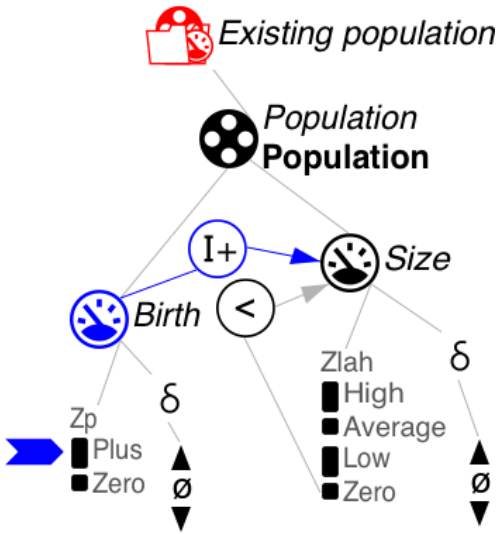
Matching - *by* Dimensions



Relating models



Feedback – “List all”

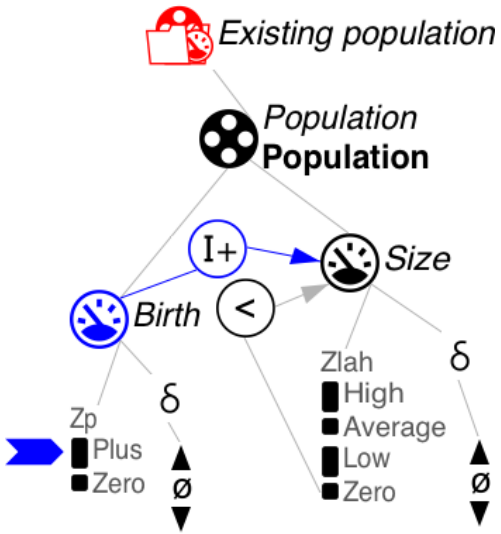


I know of models that are:

- More specific ?
- More general ?
- Analogous ?
- Inverse ?

compared to what you have…

Feedback – “Focussed”



What about modelling Mortality in addition to Birth?

Gracia, et al., 2010 (ISWC, LNCS 6414)

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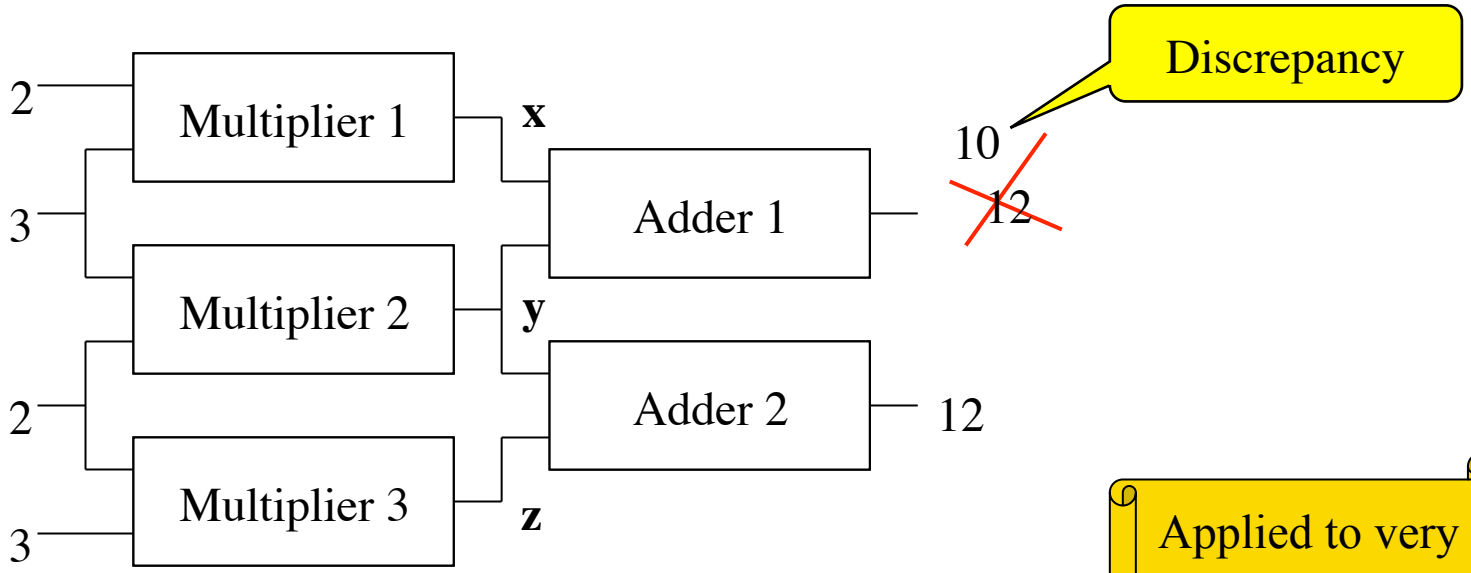
Consistency-based Diagnosis



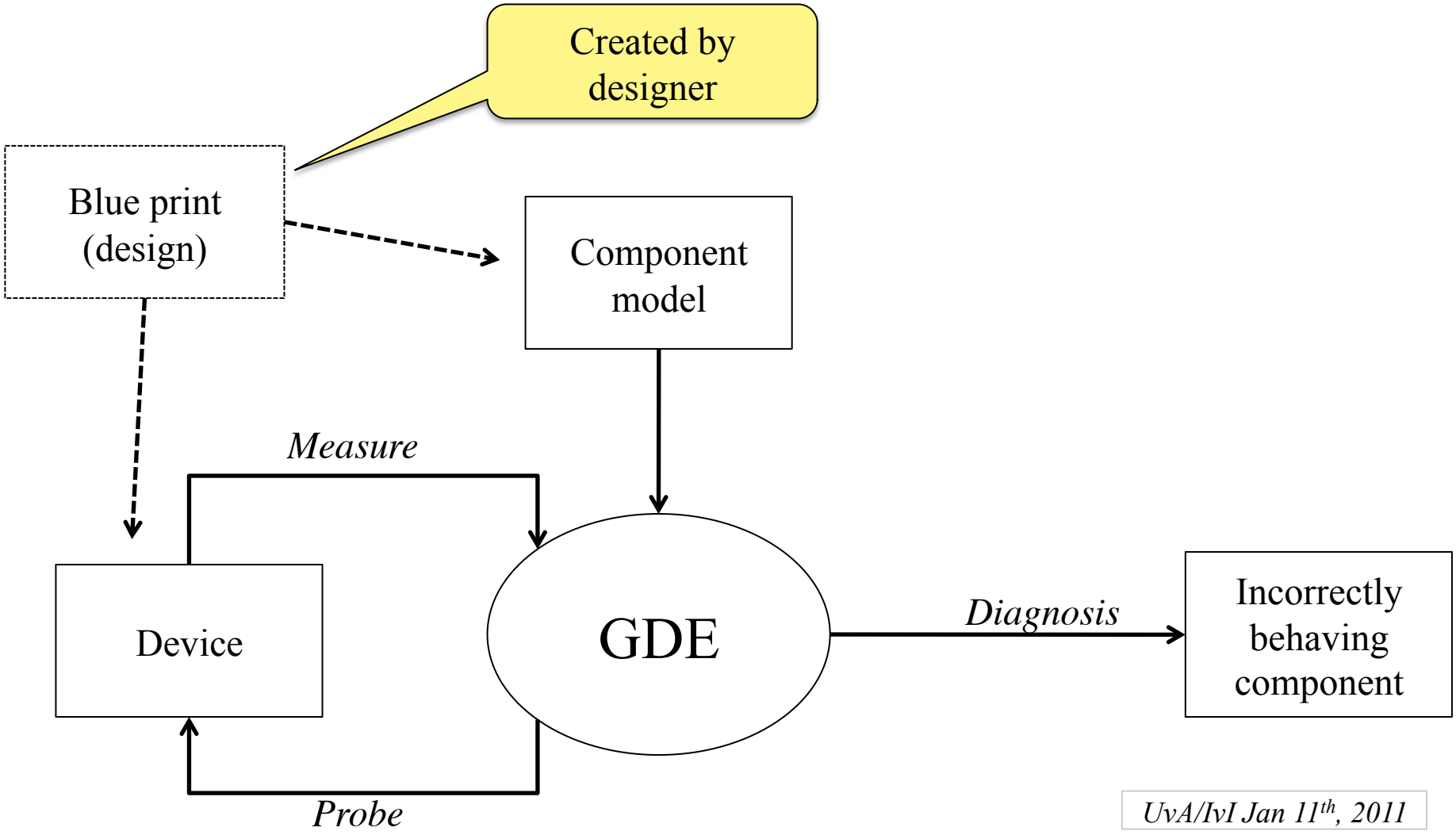
Applied to very large circuits

Conflicts {A1, M1, M2} {A1, M1, A2, M3}

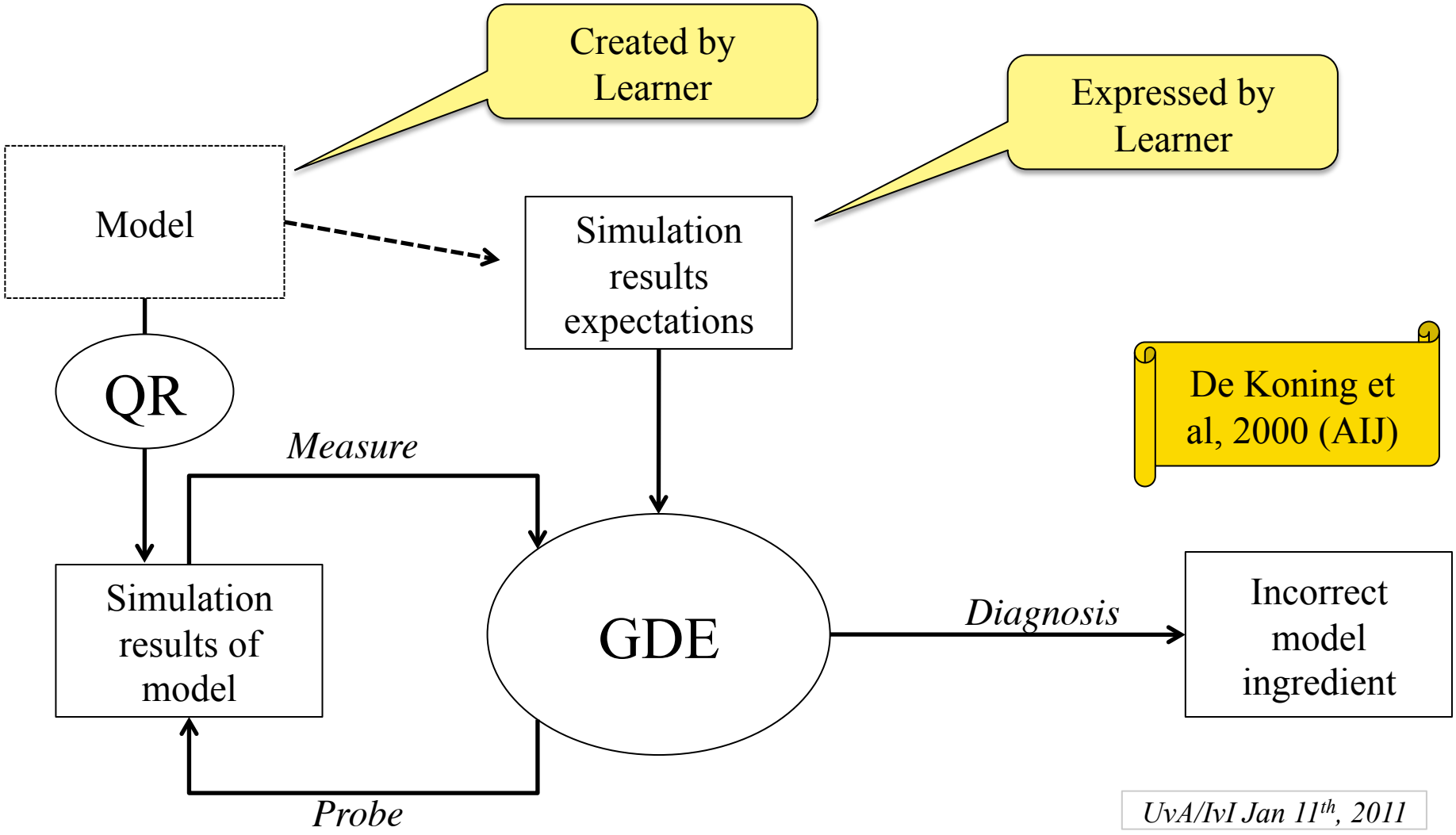
Candidates Single faults: {A1} **or** {M1} *(also multiple faults: {A2, M2})*

Measuring E.g. value at Y (or X)

CBD in technical context



CBD in learning context



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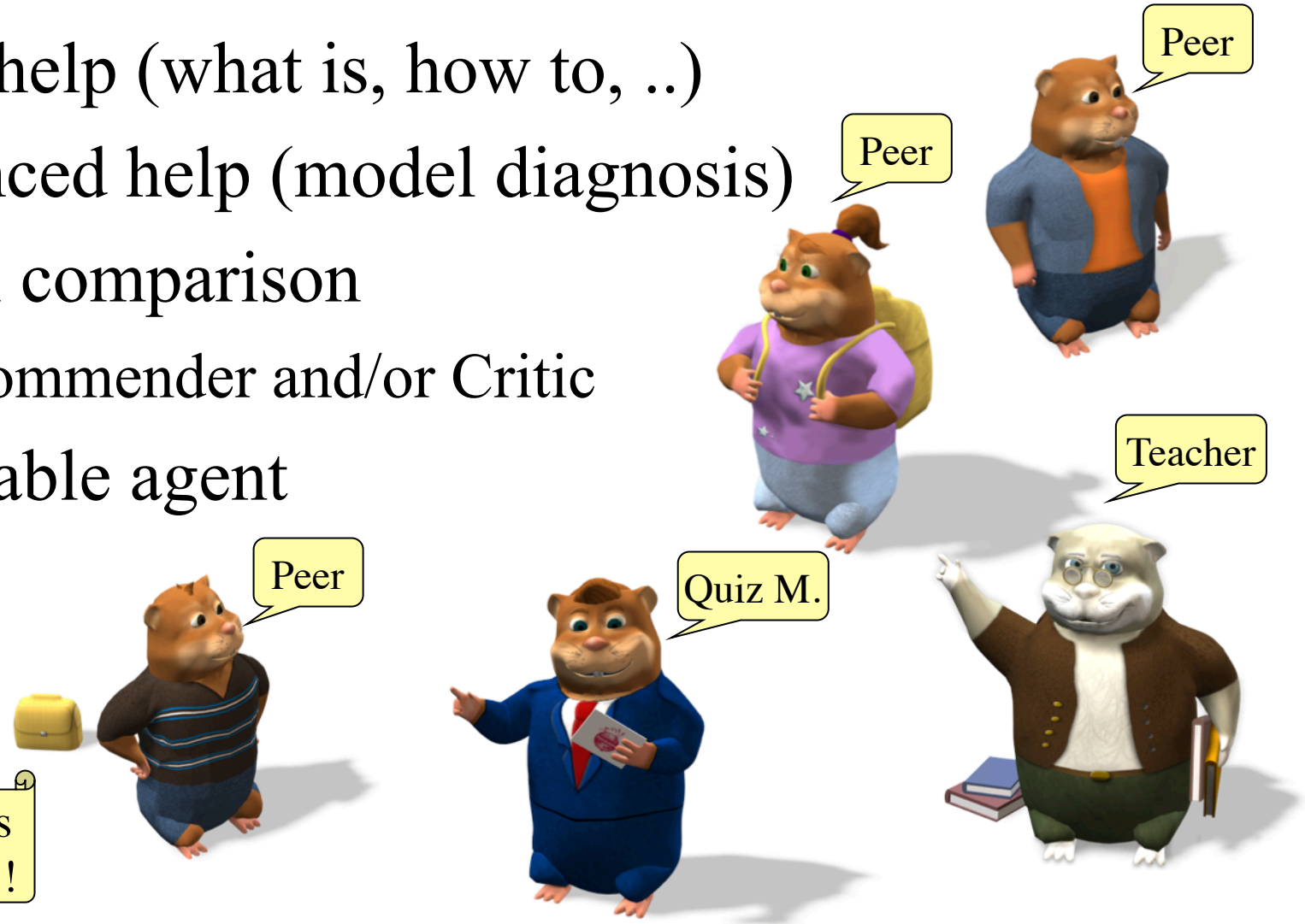
Mehlmann, et al., 2010 (IVI, LNCS 6356)

Feedback & Character roles

- Basic help (what is, how to, ..)
- Advanced help (model diagnosis)
- Model comparison
  - Recommender and/or Critic
- Teachable agent
- Quiz



Initiative always with the learner !

http://www.DynaLearn.eu

Concluding remarks

- Problem statement and Context
  - Communicative interaction (science education)
- Knowledge representation and Reasoning
  - Qualitative system dynamics / Conceptual knowledge
- Progressive learning spaces (6 spaces)
- Feedback for Reflective thought
  - Semantic Web techniques (model ingredients)
  - Consistency-based Diagnosis (simulation results)
- Inducing Motivation (virtual characters & modes)

Application & evaluation in *Environmental Science* curricula