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An intelligent learning environment for learning conceptual knowledge

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Overview

- Problem statement and Context
- Qualitative reasoning
- Progressive learning spaces
- Feedback generation (for reflective thought)
  - Basic help / Recommendations / Diagnosis
- Virtual characters
- Educational embedding and evaluation
- Concluding remarks

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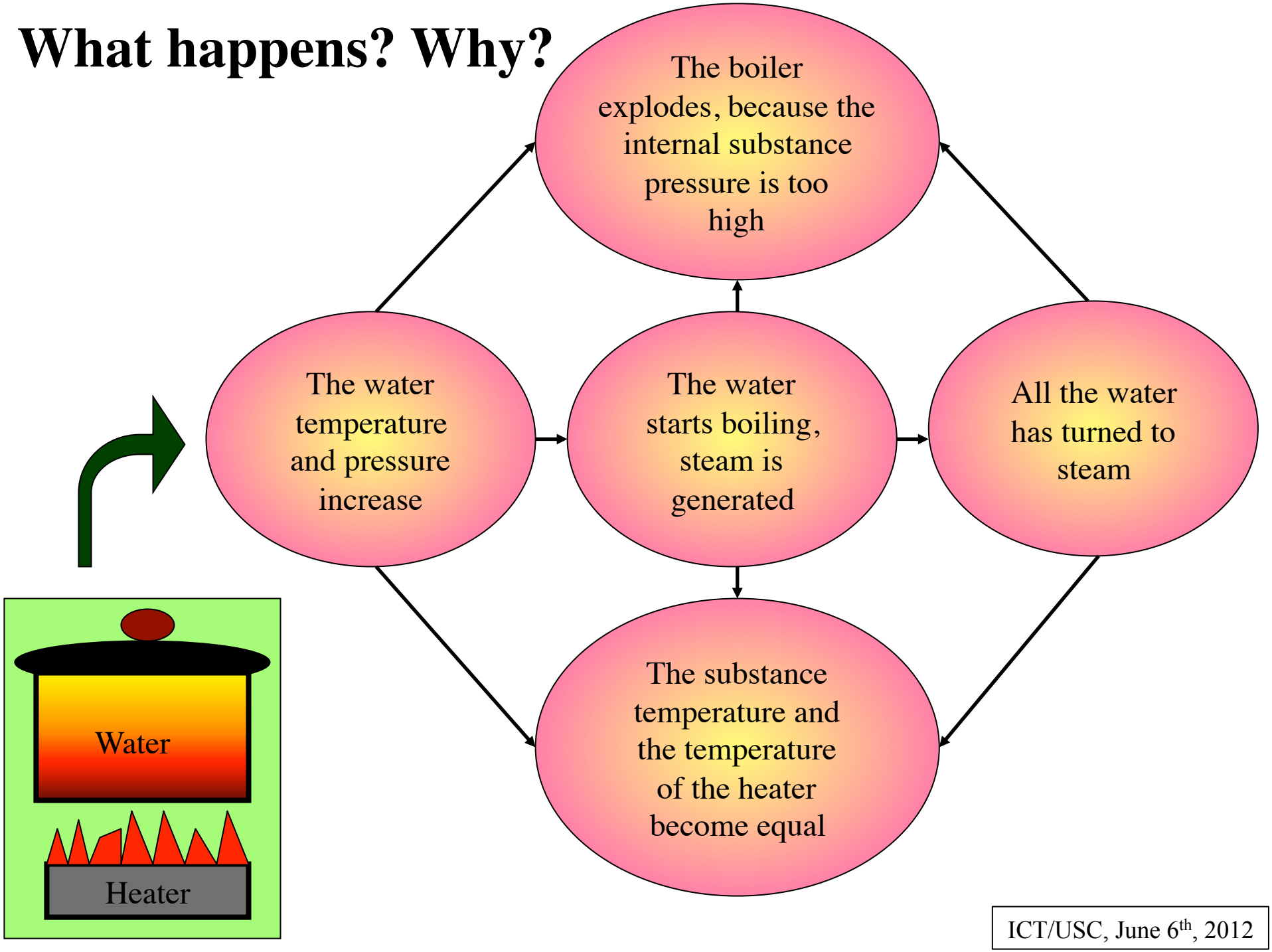
What happens? Why?



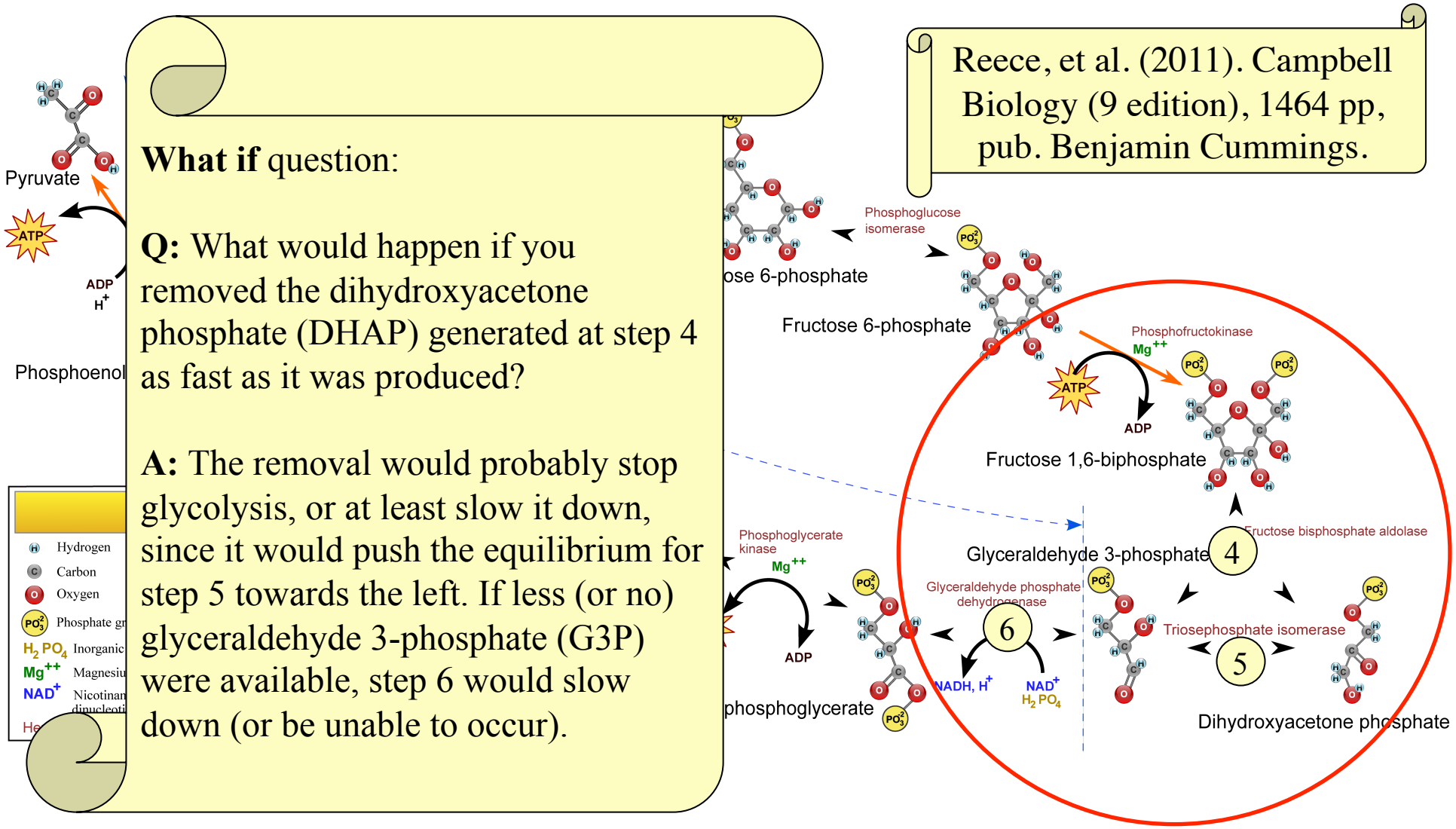
Biology – Glycolysis

Reece, et al. (2011). Campbell Biology (9 edition), 1464 pp, pub. Benjamin Cummings.

What if question:

Q: What would happen if you removed the dihydroxyacetone phosphate (DHAP) generated at step 4 as fast as it was produced?

A: The removal would probably stop glycolysis, or at least slow it down, since it would push the equilibrium for step 5 towards the left. If less (or no) glyceraldehyde 3-phosphate (G3P) were available, step 6 would slow down (or be unable to occur).



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.*

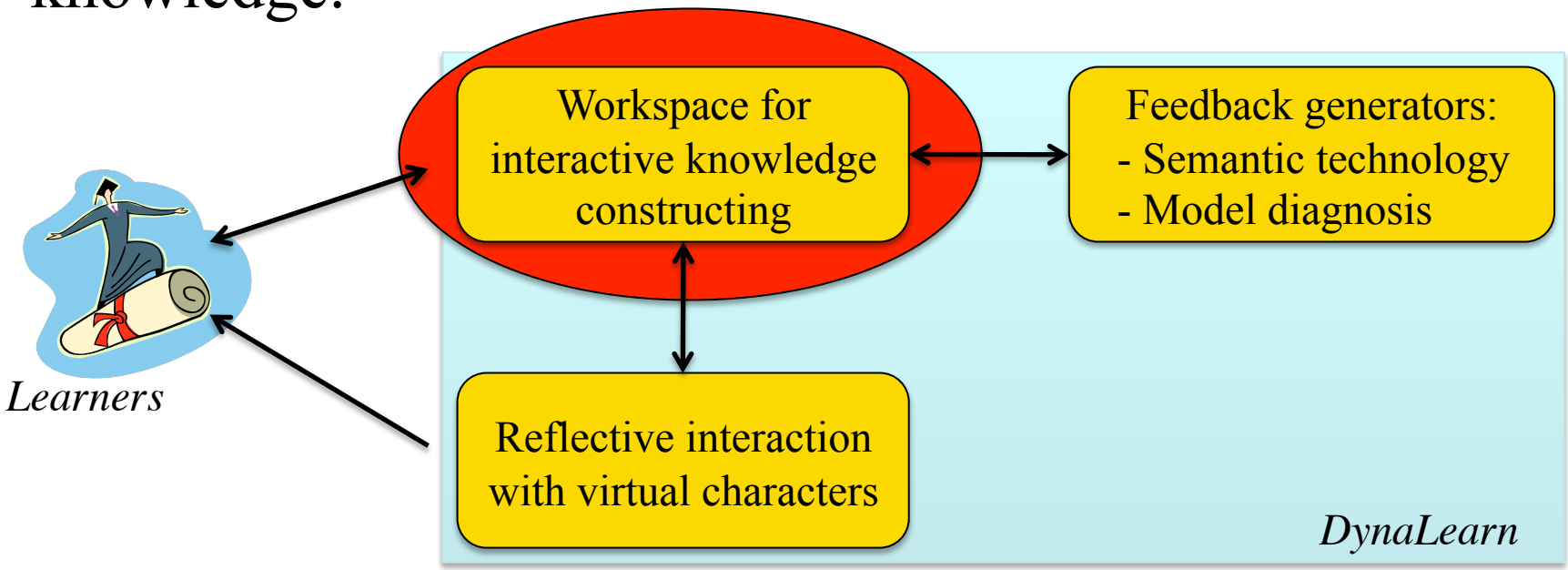
How to address these using:
Technology-Enhanced Learning (EC-TEL)

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.



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

Integrate proven technology

DynaLearn - Main objective

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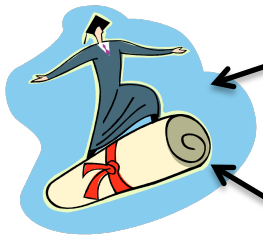
arners to const *eptual* system

Accommodate the ***true nature*** of conceptual knowledge

React to the ***individual*** knowledge needs of learners

Workspace for interactive knowledge constructing

Feedback generators:
- Semantic technology
- Model diagnosis



Learners

Reflective interaction with virtual characters

Be ***engaging*** by using personified agent technology

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

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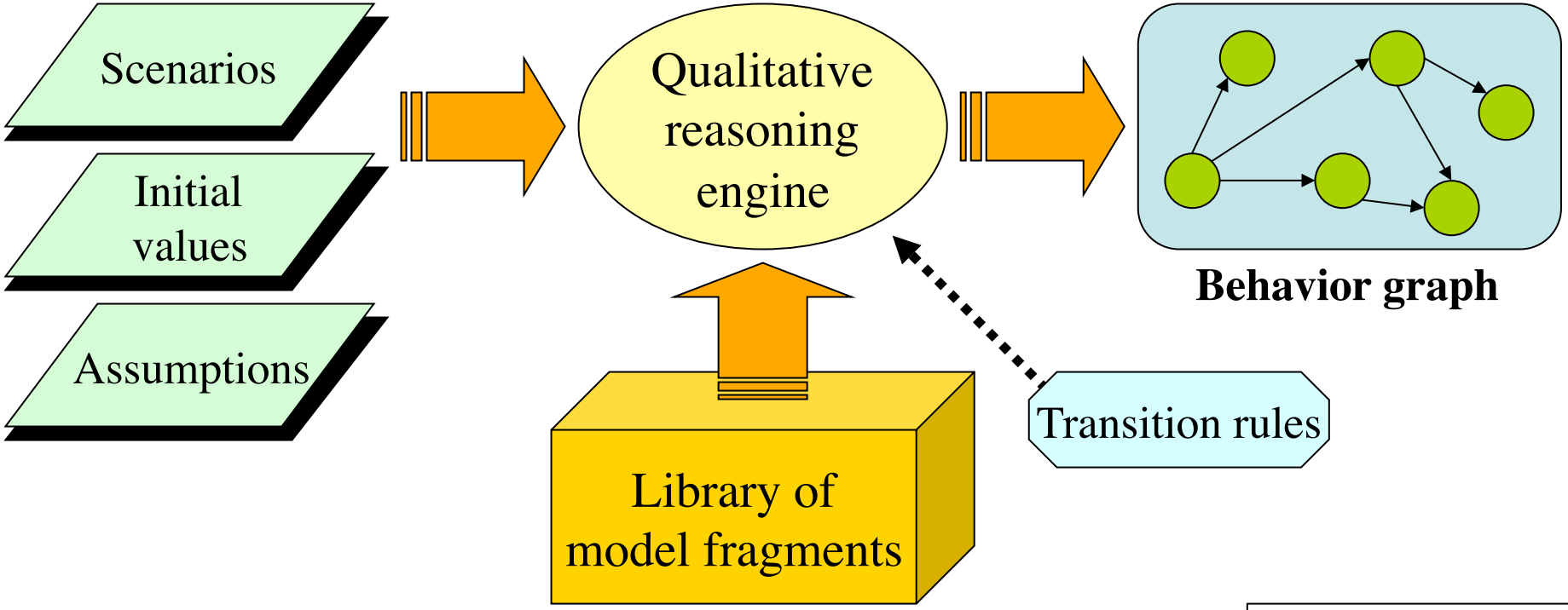
Qualitative Reasoning Engine

26th Int. Workshop: Playa Vista, CA, USA, July 16-18, 2012
- Multiple domains (e.g. Physics, Ecology, Economics, ..)
- Multiple tasks (Education, Device diagnosis, Robotics navigation, ..)



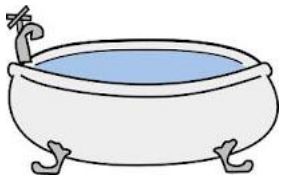
Constructing knowledge

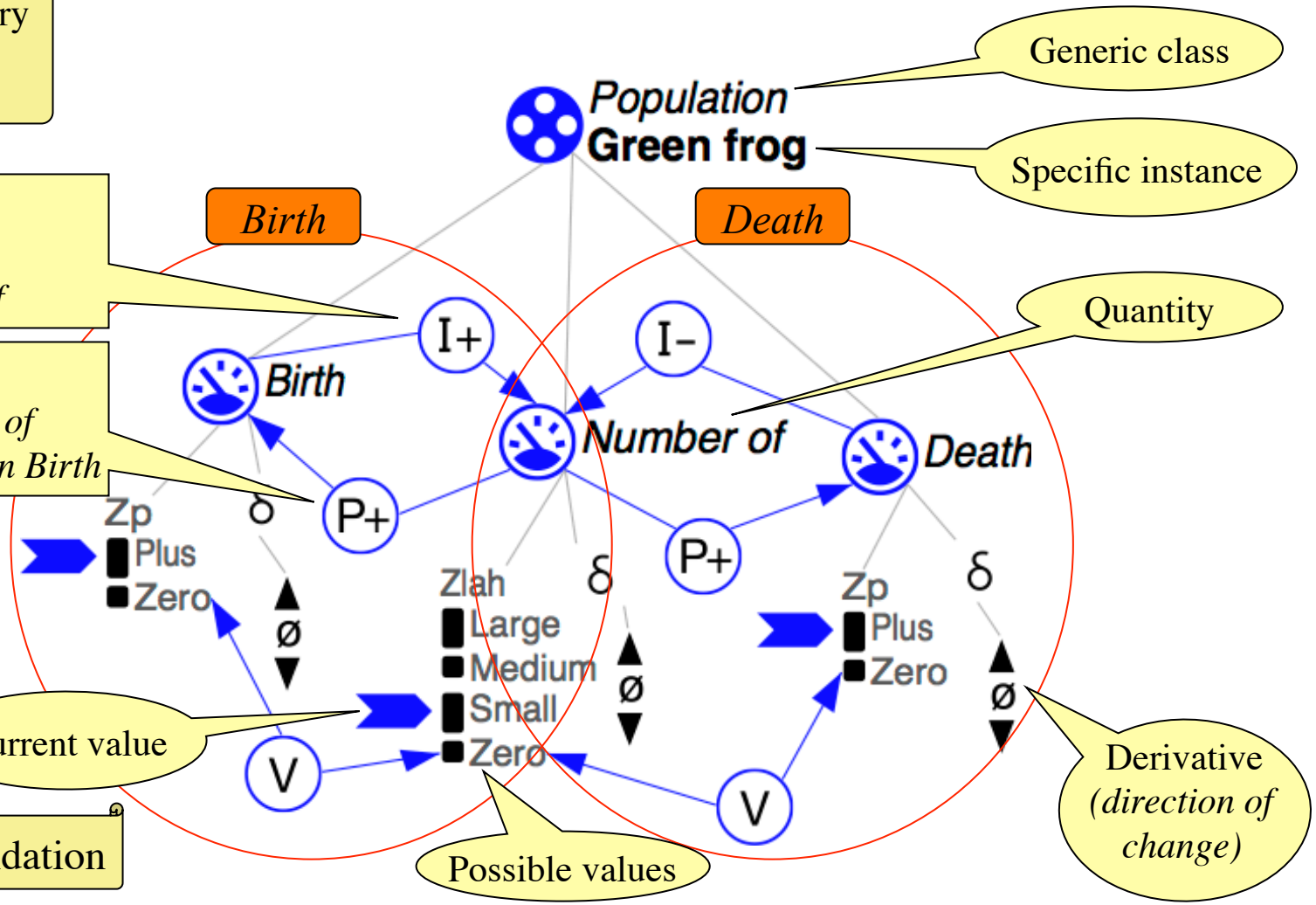
Population dynamics

- Generic vocabulary
- Visualisation
- Domain facts

Influence:
The amount of Birth increases Number of

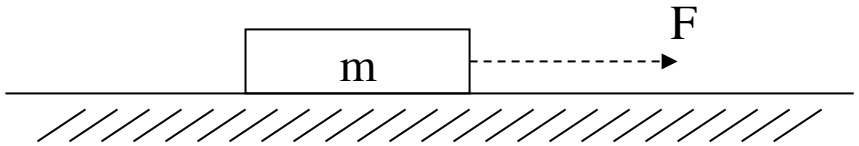
Proportionality:
Changes in Number of determine changes in Birth





Mathematical foundation

Causality → Directedness

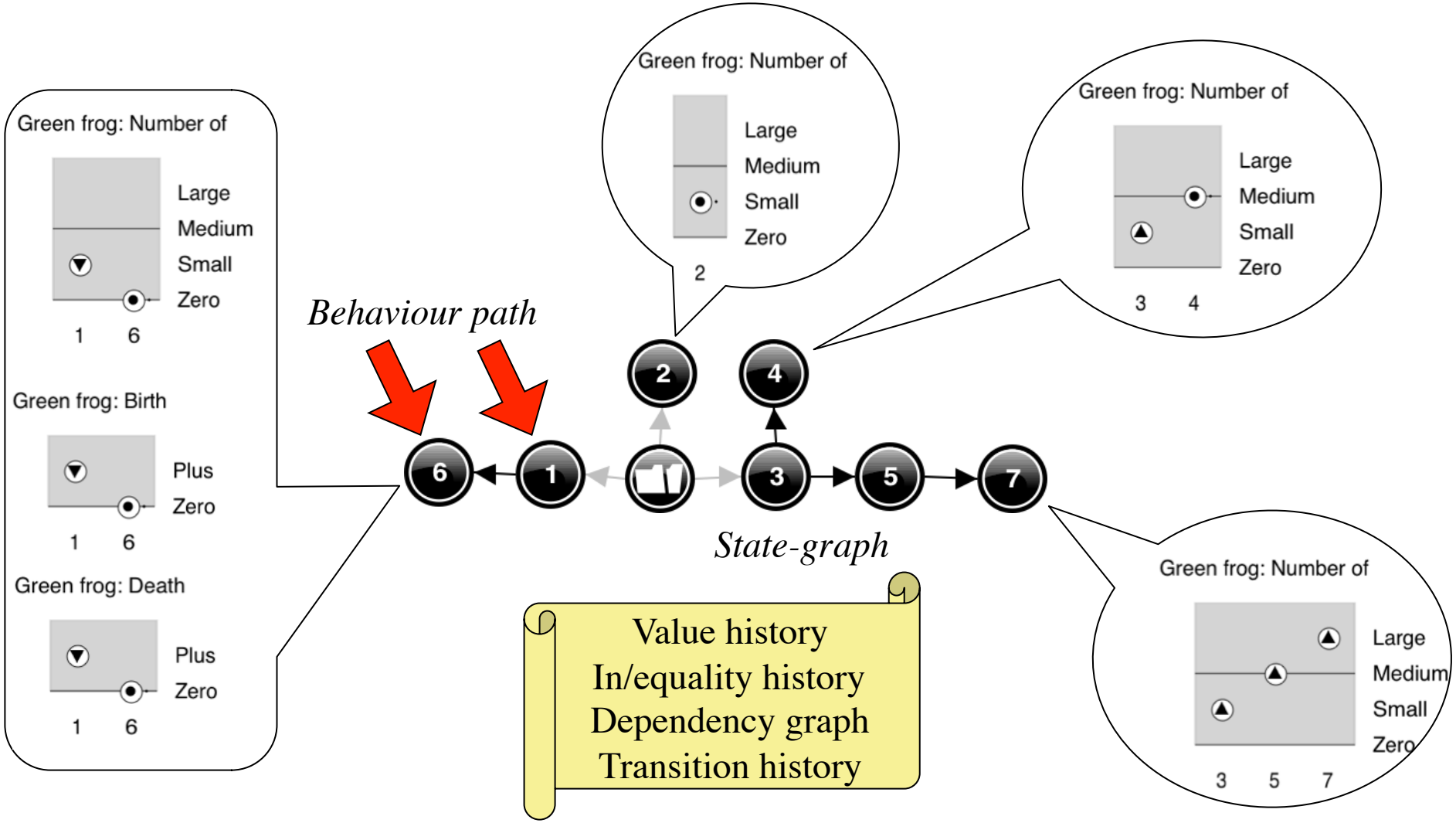


F = m * a

- 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 …

Simulation results

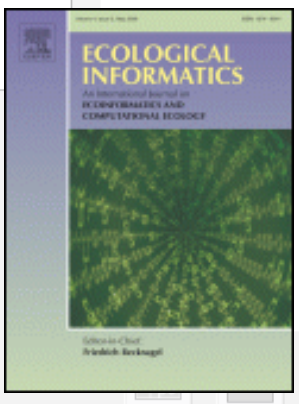
State-graph & Behaviour Paths



NaturNet-Redime

http://www.garp3.org

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



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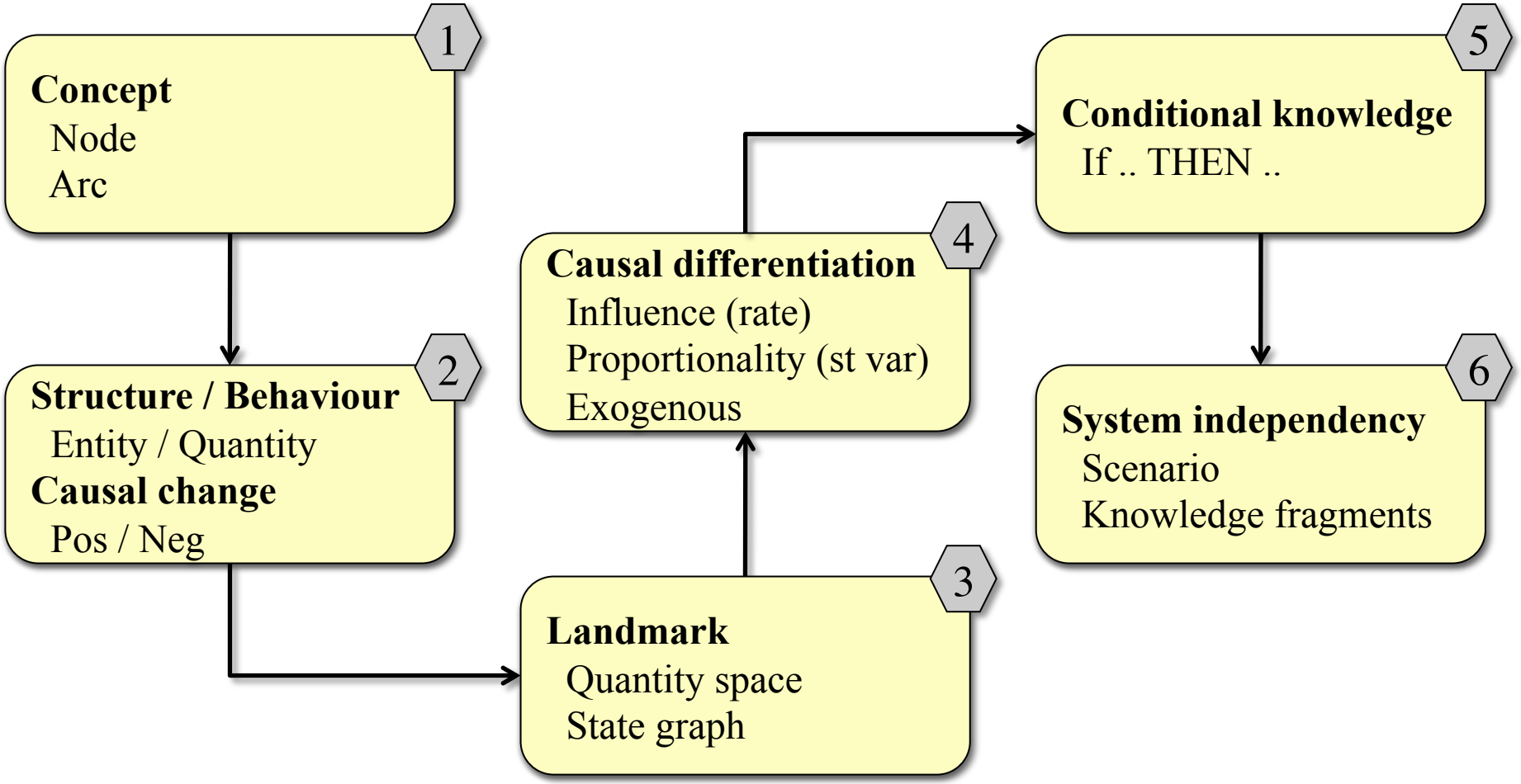
Representation scaffolds

- 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.

Progression of Learning Spaces



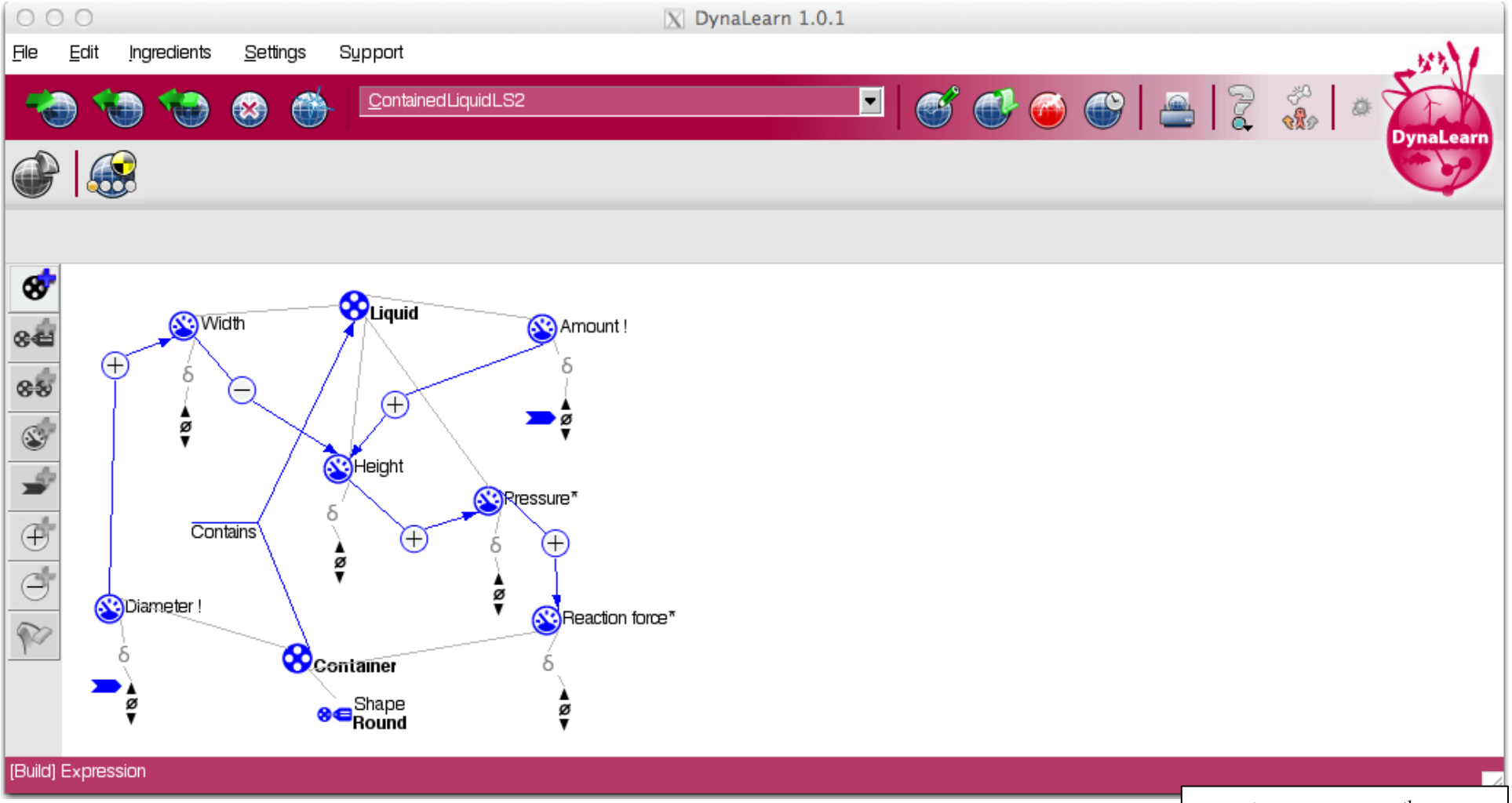
Progression of Learning Spaces

Learning space 2: Basic causal model

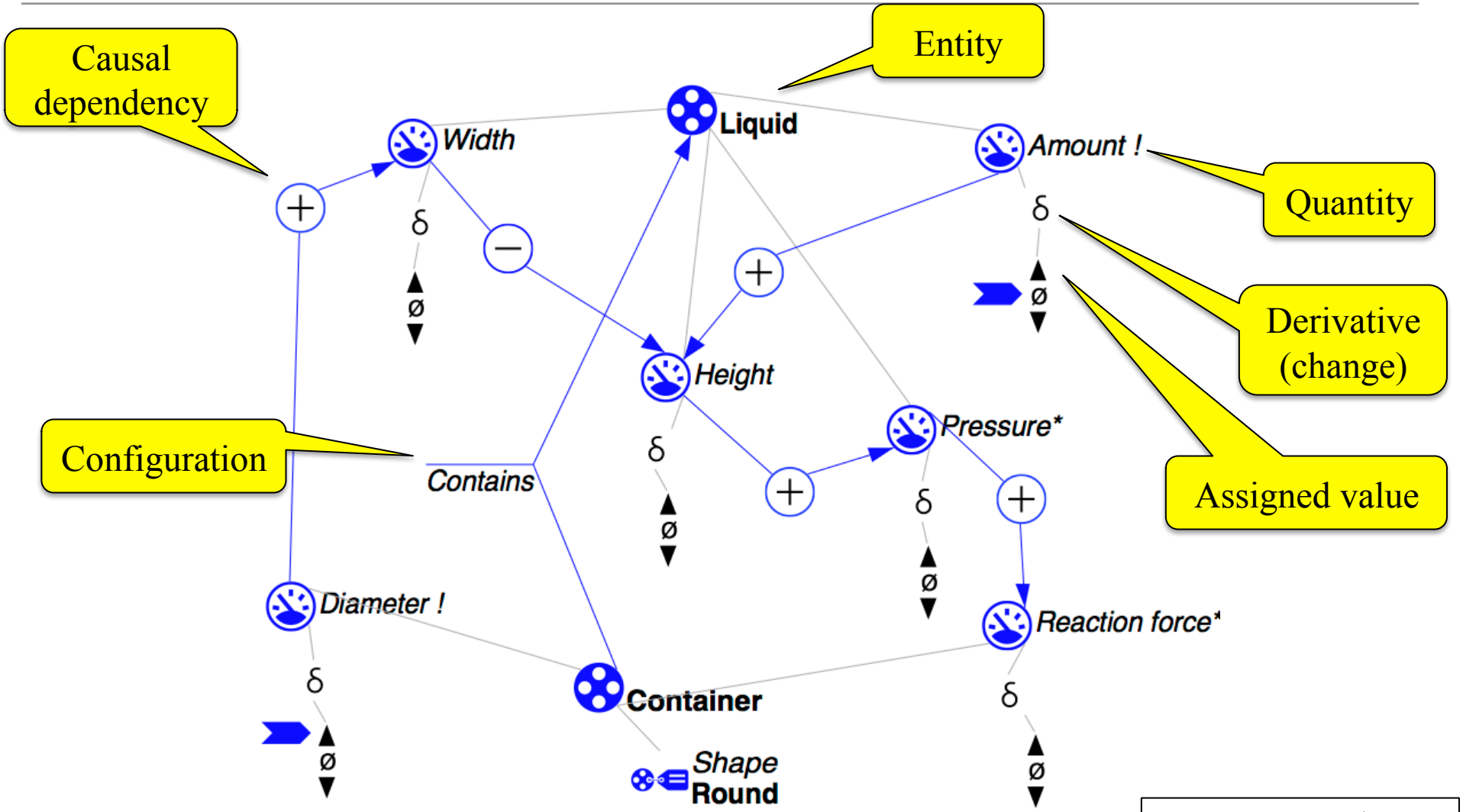
What constitutes the system?
Structure vs. behaviour

How do changes propagate through the system?
Positive / Negative causal dependencies

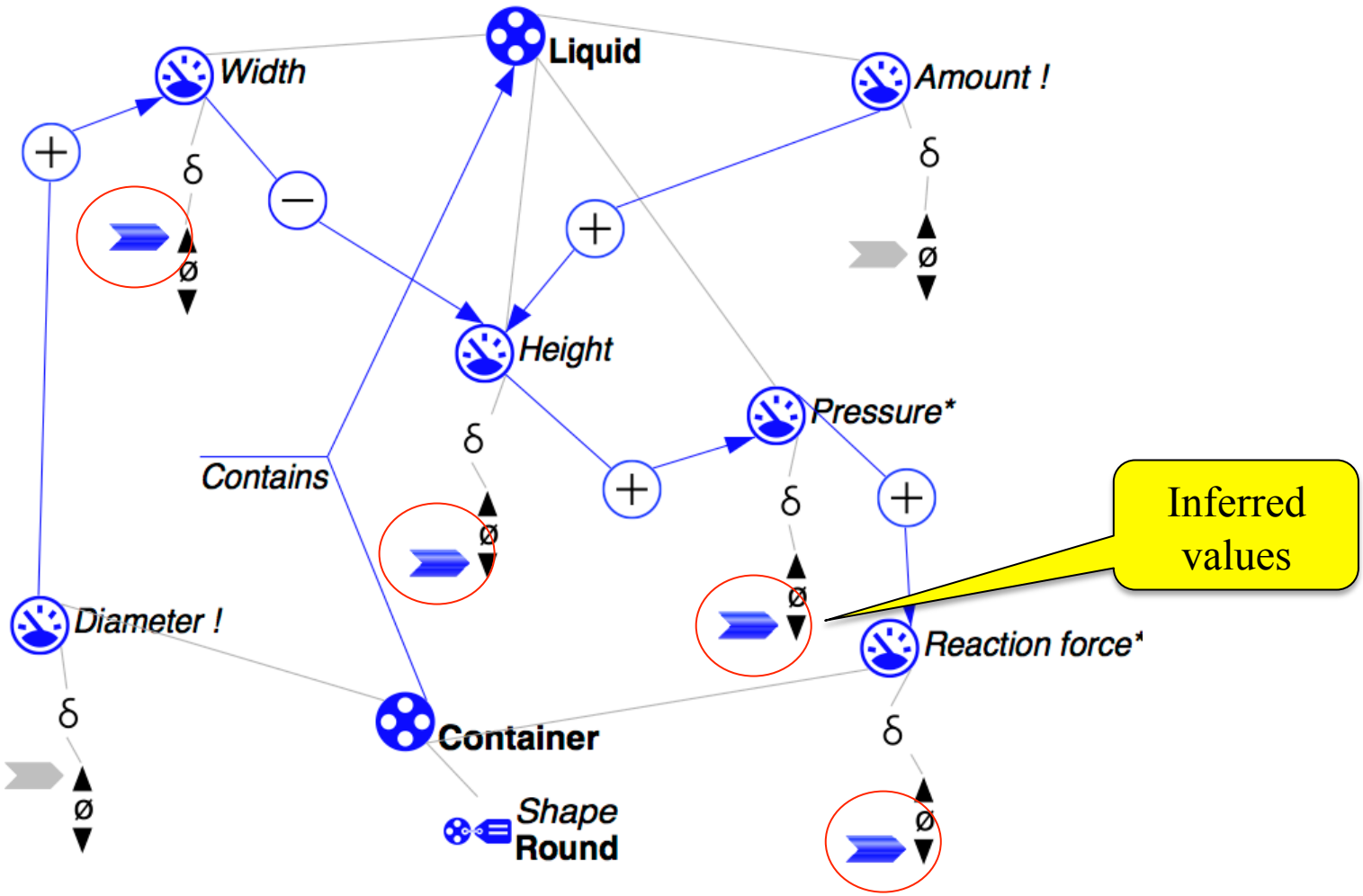
DynaLearn - Learning Space 2



LS2 - Causal model (Building)



LS2 - Causal model (Simulating)



What is discovered at LS2?

E.g. lecture on *greenhouse effect*

- 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

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Feedback & Interaction

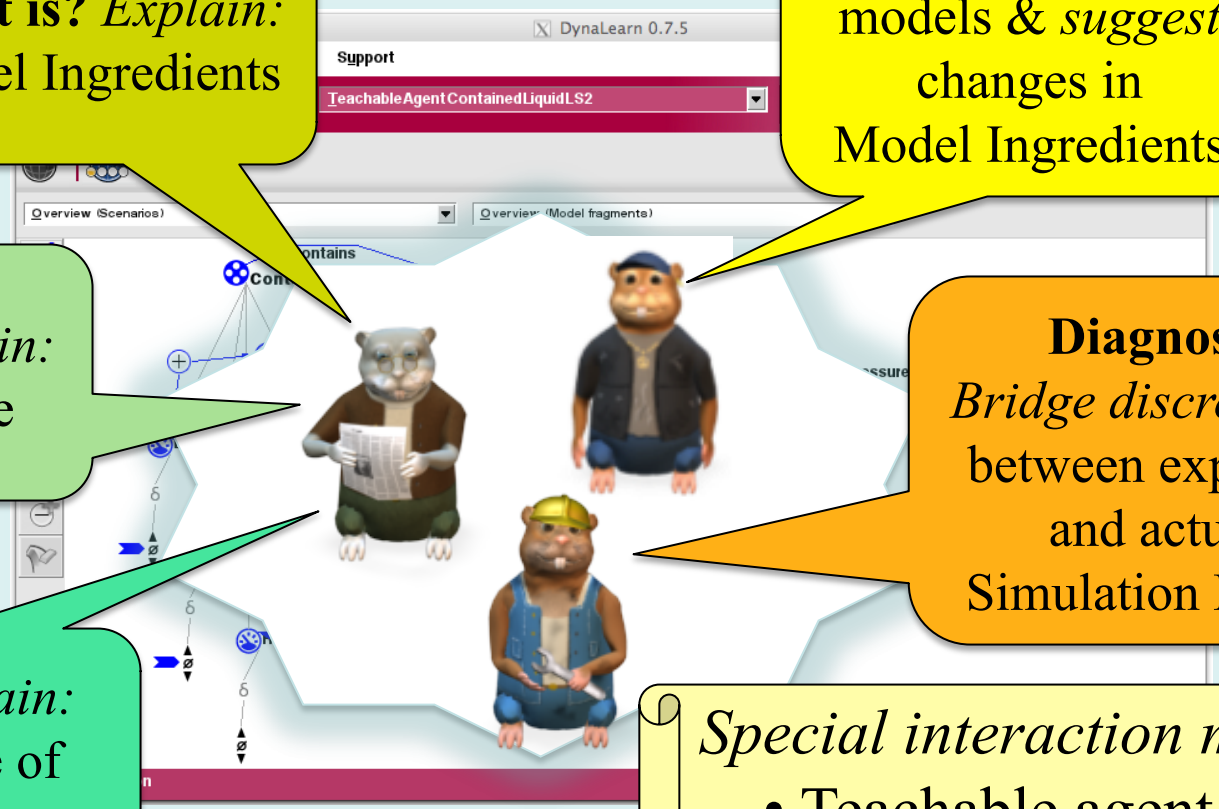
What is? *Explain:*
Model Ingredients

Recommendation
Compare to other models & *suggest* changes in Model Ingredients

How to? *Explain:*
User-Interface

Diagnosis
Bridge discrepancy between expected and actual Simulation Result

Why? *Explain:*
Occurrence of value changes



Special interaction modes:

- Teachable agent
- Quiz using existing model

http://www.DynaLearn.eu

Project Partners

UVA (Netherlands)

TAU (Israel)

UPM (Spain)

UH (UK)

UAU (Germany)

IBER (Bulgaria)

FUB (Brazil)

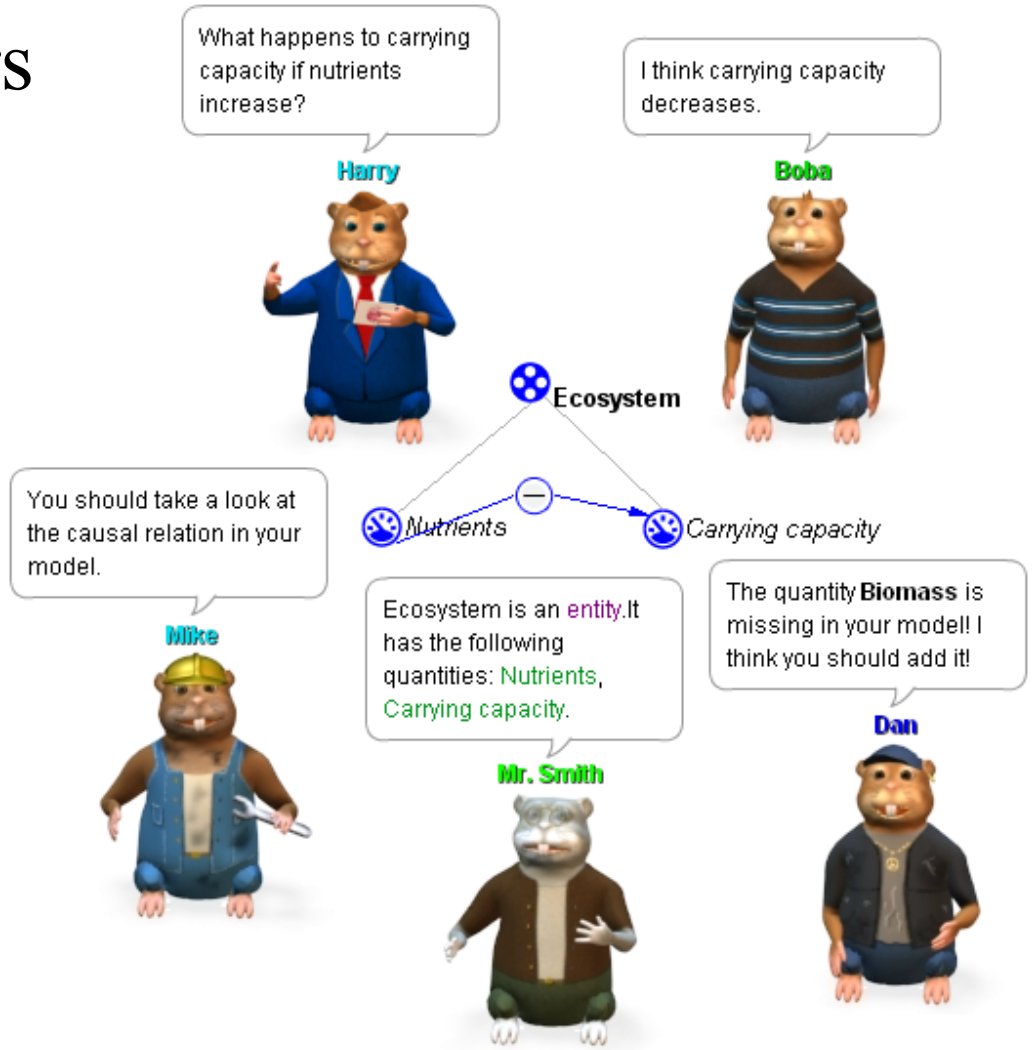
BOKU (Austria)

Hamster community - Choices

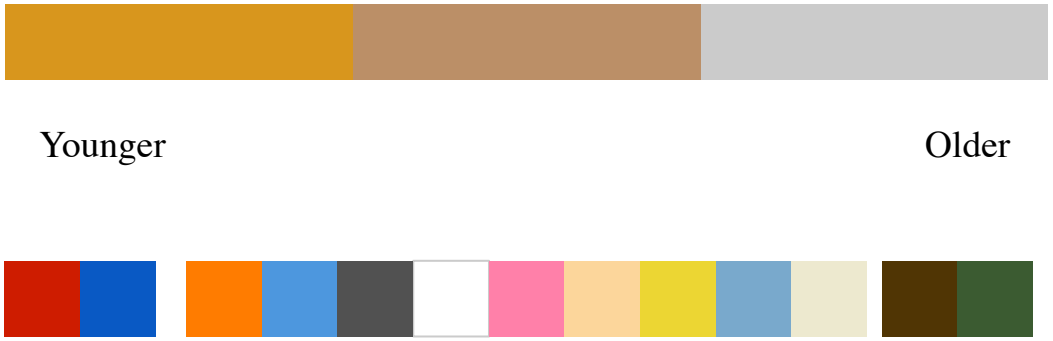
- Subject matter: Environmental science
  - Animals reflect human-environment interaction
- Intelligent impression required (but modest)
- Plausible human-like features
  - Requires exaggeration: Cartoonish graphical style
- Schoolyard scenario
  - Reflection of Learners' Situation

Support roles

- Different characters (personalities) for different types of support and knowledge



Colour Sets



Properties and details

- Props and details to categorize and group by
  - Function for the learner
  - Hamster community role

precisely dressed
hair tuft for discipline

best suit for
seriousness

spiky hair tips
for cheeky look

modern clothing style for
up-to-date mentality

eyeglasses accessory
as wisdom symbol;
also used during gestures

traditional clothing style
for down-to-earth
mentality

helmet and tool
to solve problems

colorful but worn look
showing dynamism and
experience

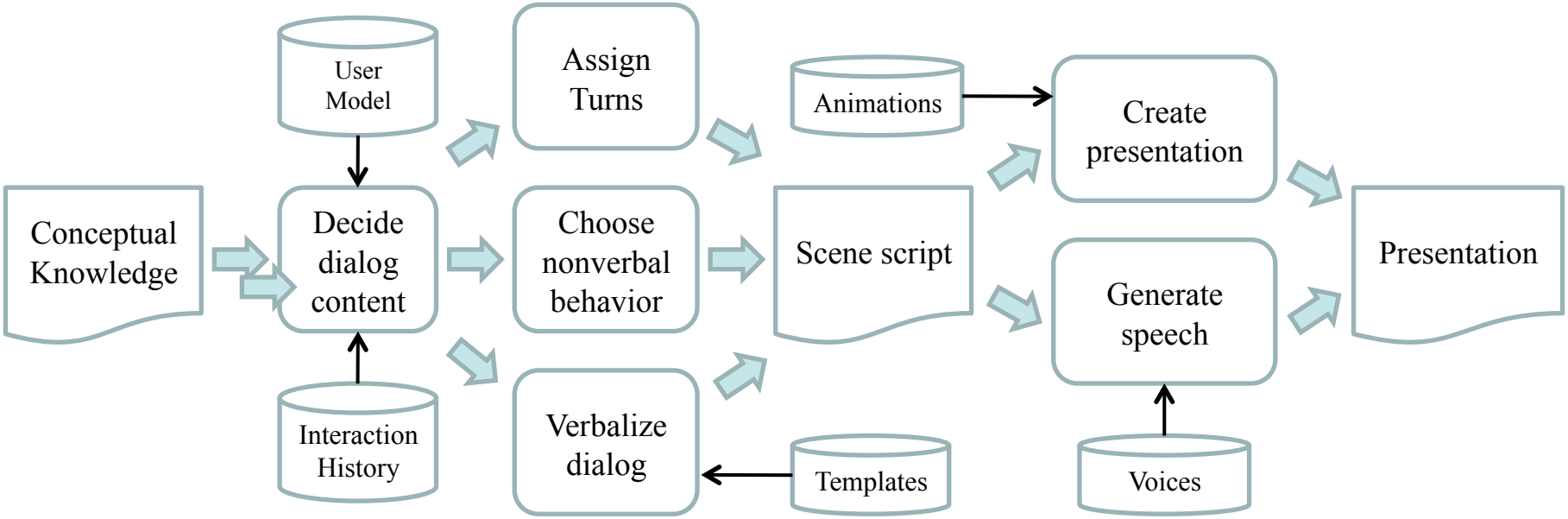
Motion and Gesture Space

- Aspects in Animation
  - Consumed Space / Spatial Extension
  - Speed of Motion / Timing

- Tight Gesture space close to Body
- Calm deliberate Motion

- Wide Gesture space
- Quick Extensive Motion

Virtual Characters - Architecture



Teachable Agent

- Learner learns with Teachable Agent
  - Behavior aims on peer-like relationship
  - Designed to have a low competency
  - Helps to promote self-efficacy and self-confidence
- Interaction with the Teachable Agent:
  - Ask question about the model
  - Let it explain its reasoning
  - Challenge in a quiz with the quizmaster

Based on learner's model

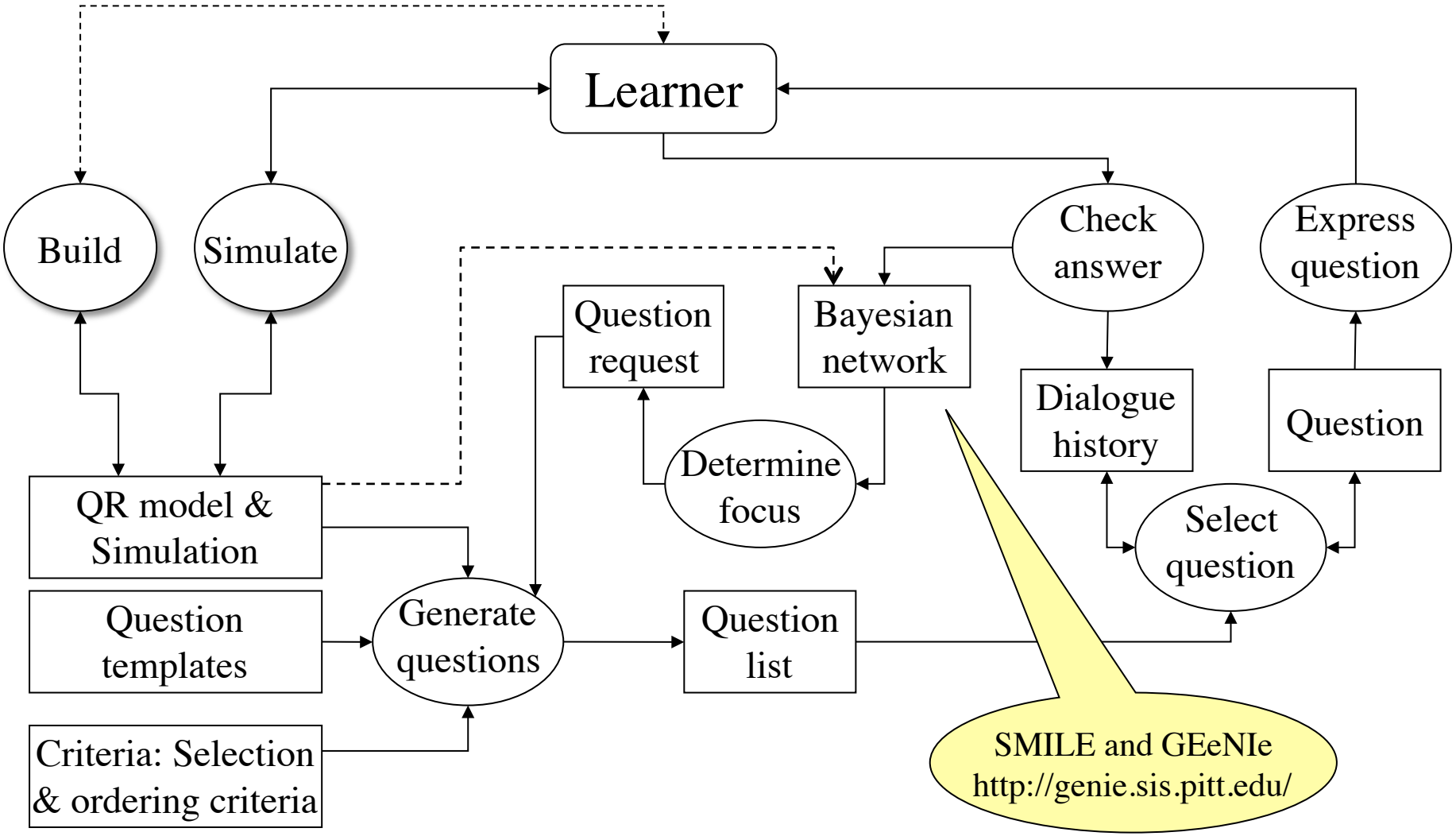
Based on expert's model

Teachable agent- Movie

Integrated dialogues

- Getting to know a model
  - Basic Help for familiarization and Quiz on the topics covered so far afterwards
- Model building support
  - Combination of Diagnosis and Recommendation
- Assisted model building
  - Learners instructed by specific Recommendations while the Basic Help explains the necessary model ingredients and concepts

Question generation



Integrated dialogue - Movie

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Educational embedding

- Curriculum opportunities (what? where? how?)
- Course materials
  - Explanatory models for repository
  - Assignments (fully build, repair, augment, analogy)
- Evaluation studies
- Research questions
  - Does the QR meta-vocabulary provide an analytic instrument for learners to learn (better)?
  - Do the virtual characters induce the 'involvement momentum'?
  - Do the feedback instruments adequately support learners in acquiring the subject matter?

Evaluation studies

- Preliminary results:
  - Mioduser, et. al. (2012). Final report on DynaLearn evaluation studies. EC FP7 231526, D7.4, 100 pages.
- 49 evaluation activities (partially formative studies)
  - Learners, but also Teachers
- 736 participants in total
- "DynaLearn has proven to be of great potential for supporting student's learning of systems and complex phenomena." (page 41)

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Concluding remarks

- Qualitative vocabulary and reasoning
  - Rich and articulate
  - Strong basis for Communicative interaction
  - Ontology for Qualitative System Dynamics
- Managing learning complexity
  - Progression via six unique learning spaces
- Virtual characters
  - Seems to induce motivation
  - For younger age groups
- DynaLearn ILE: Tool for studying learning