An intelligent learning environment for learning conceptual knowledge

Bert Bredeweg
Informatics Institute, Faculty of Science
University of Amsterdam, Netherlands

This work is co-funded by the EC within FP7, Project no. 231526, http://www.DynaLearn.eu
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
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
The water temperature and pressure increase. The water starts boiling, steam is generated. All the water has turned to steam. The substance temperature and the temperature of the heater become equal. The boiler explodes, because the internal substance pressure is too high.

What happens? Why?

ICT/USC, June 6th, 2012
**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…

ICT/USC, June 6th, 2012
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
To develop an interactive learning environment that allows learners to construct their conceptual system knowledge. DynaLearn - Main objective

- Accommodate the **true nature** of conceptual knowledge
- React to the **individual** knowledge needs of learners
- Workspace for interactive knowledge constructing
- Reflective interaction with virtual characters
- Feedback generators:
  - Semantic technology
  - Model diagnosis
- Be engaging by using personified agent technology

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

Integrate proven technology

DynaLearn - ICT/USC, June 6th, 2012
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
Qualitative Reasoning Engine

- 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

Generic class
Specific instance
Quantity
Current value
Possible values
Derivative (direction of change)

ICT/USC, June 6th, 2012
Causality → Directedness

- 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

Behaviour path

State-graph

Value history
In/equality history
Dependency graph
Transition history
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
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

1. Concept
   - Node
   - Arc

2. Structure / Behaviour
   - Entity / Quantity
   - Causal change
   - Pos / Neg

3. Landmark
   - Quantity space
   - State graph

4. Causal differentiation
   - Influence (rate)
   - Proportionality (st var)
   - Exogenous

5. Conditional knowledge
   - If .. THEN ..

6. System independency
   - Scenario
   - Knowledge fragments

ICT/USC, June 6th, 2012
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 (Simulating)

Inferred values

ICT/USC, June 6th, 2012
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

E.g. lecture on
greenhouse effect

ICT/USC, June 6th, 2012
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
Feedback & Interaction

What is? Explain: Model Ingredients

How to? Explain: User-Interface

Why? Explain: Occurrence of value changes

Recommendation
Compare to other models & suggest changes in Model Ingredients

Diagnosis
Bridge discrepancy between expected and actual Simulation Result

Special interaction modes:
- Teachable agent
- Quiz using existing model

ICT/USC, June 6th, 2012
Project Partners

UVA (Netherlands) ✔️

TAU (Israel)

UPM (Spain)

UH (UK)

UAU (Germany) ✔️

IBER (Bulgaria)

FUB (Brazil)

BOKU (Austria)

http://www.DynaLearn.eu

ICT/USC, June 6th, 2012
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

ICT/USC, June 6th, 2012
Support roles

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

ICT/USC, June 6th, 2012
Colour Sets

Younger

Lively

Older

Calm
Properties and details

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

- precisely dressed
  - hair tuft for discipline

- spiky hair tips
  - for cheeky look

- eyeglasses accessory
  - as wisdom symbol;
  - also used during gestures

- helmet and tool
  - to solve problems

- best suit for
  - seriousness

- modern clothing style for
  - up-to-date mentality

- traditional clothing style
  - for down-to-earth
  - mentality

- 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

Conceptual Knowledge

- Decide dialog content
  - User Model
  - Interaction History

- Assign Turns
  - Assign Turns

- Choose nonverbal behavior
  - Choose nonverbal behavior

- Verbalize dialog
  - Verbalize dialog

Scene script

- Scene script
  - Animations
  - Templates

Create presentation

- Create presentation
  - Generate speech
    - Generate speech
      - Voices

Presentation

ICT/USC, June 6th, 2012
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
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

Learner

Build
Simulate

QR model & Simulation
Question templates
Criteria: Selection & ordering criteria

Generate questions

Question request
Bayesian network

Check answer
Dialogue history

Express question
Select question

SMILE and GEnIe
http://genie.sis.pitt.edu/
Integrated dialogue - Movie
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
Project Partners

UVA (Netherlands)  ✔  TAU (Israel)

UPM (Spain)  ✔  UH (UK)

UAU (Germany)  ✔  IBER (Bulgaria)

FUB (Brazil)  ✔  BOKU (Austria)

http://www.DynaLearn.eu

ICT/USC, June 6th, 2012
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)
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
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