Acquiring conceptual knowledge on how systems behave using Qualitative Reasoning technology

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Overview

• Introduction
  – Problem statement & context
  – Main objective

• Constructing conceptual knowledge
  – Example
  – Learning-by-conceptual-modelling
  – Learning spaces

• Educational components
  – Semantic technology
  – Virtual characters
  – Example: quiz
  – Science curricula

• Evaluation & conclusion
Problem statement

• Worrying decline in science curricula
  – Less students sign up
  – More students drop out

• Main reasons
  – Lack of engagement and motivation in science teaching
  – Teaching involves surface knowledge in terms of formulas and uninterpreted numeric data
  – Lack of interactive tools to construct conceptual knowledge

  e.g. Osborne et al. 2003
Having learners acquiring *conceptual* knowledge of system’s behaviour:

- Deep knowledge in terms of the *concepts* that are involved
- Learn basic principles that can be *carried over* to other problem instances
- Learn 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
- *Communicate* insights to the general public
DynaLearn - Main objective

• To develop an interactive learning environment that allows learners to construct their conceptual system knowledge, either individually or in a collaborative setting.

• Strategic characteristics:
  – Accommodate the true nature of conceptual knowledge
  – Be engaging by using personified agent technology
  – React to the individual knowledge needs of learners
  – Applied to the interdisciplinary curriculum of environmental science
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Example

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 …
Learning-by-conceptual-modelling

• Modelling is fundamental to human cognition and scientific inquiry (cf. Schwarz & White, 2005)
• Simulations mimic the behaviour of real-world systems.
• Conceptual Reasoning captures the human interpretation of reality:
  – Couched in the appropriate vocabulary
  – Remove numerical ‘overhead’
  – Provides handles to automate interaction
Explicitizing the *semantics* of the domain

- **Scope**: Which aspects of the system should be included in the model? (relevant/irrelevant)
- **Granularity**: What is the level of detail that should be modeled?
- **Compositionality**: How must knowledge be put in modules in order to allow *knowledge reuse*?
- **Conditionality**: Under what conditions do certain knowledge modules apply?

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

Supporting domain experts with theory development

Automated conceptual reasoner

Tutoring & training

Stakeholder management

JTEL 2010
Learning spaces

1. Concept map
2. Causal model
   - single state
   - derivatives
3. Casual state graph
   - correspondences
   - magnitudes
4. Causal Differentiation
   - propagation
   - rates
5. Conditional knowledge
6. Knowledge Re-use
   - scenarios
   - fragments

JTEL 2010
Expressing conceptual knowledge
(learning space 2)
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Semantic technology

Expert/teacher

Student

http://dbpedia.org/resource/Size
http://dbpedia.org/resource/Population
http://dbpedia.org/resource/Mortality_rate

grounding

Semantic repository

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Feedback and recommendation

- e.g., “You can complete your model with a P+ proportionality”
- e.g., “Users who modelled death also modelled birth”

DynaLearn

Student

Expert

Community of users
Engaging virtual characters

- Handling complex knowledge
- Handling large amounts of knowledge in a rich vocabulary
- Use different agents for different kinds of knowledge
- Drama-based learning: VCs interacting with the learner and with one another
- Natural Language Generation and Speech Synthesis
Character roles

• Basic help (what is, how to, ..)
• Advanced help (model diagnosis)
• Teachable agent
• Model comparison
• Critic
• Quiz
Use case: Teachable agent

Biswa, et al. (Betty's Brain)
Science curricula

• Interdisciplinary approach: Environmental science
• Rethink the administration of the subject matter
• Establish semantic repository of explanatory models
• Create lesson plans
• Blend in with ongoing classroom learning activities
Project beneficiaries

- University of Amsterdam (UvA - Netherlands)
- Universidad Politécnica de Madrid (UPM - Spain)
- University of Augsburg (UAU - Germany)
- University of Brasília (FUB - Brazil)
- Tel Aviv University (TAU - Israel)
- University of Hull (UH - United Kingdom)
- Bulgarian Academy of Sciences (CLGE - Bulgaria)
- University of Natural Resources and Applied Life Sciences (BOKU - Austria)
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Typical evaluation questions

• Does the DynaLearn diagrammatic approach allow learners to address more complex problems?
• Does the meta-vocabulary from which a conceptual interpretation is built, provide an analytic instrument that enables learners to construct more fine grained and thorough analyses of how systems work?
• Do the embodied conversational agents establish the ‘involvement momentum’ required?
• Do the instruments to individualise learning (ontology mapping, diagnostic procedures, and semantic repository) adequately steer learners in acquiring the target subject matter?
• Does the personal autonomy cause learners to be more motivated?
• Do learners actually learn better when using the full set of DynaLearn results? And are students more motivated to take on science curricula?
Conclusions & expectations

• Allows learners to articulate, analyse and communicate ideas, and thereby
  – Construct conceptual knowledge about scientific theories
• Engages learners in science education
• Reduces the perceived complexity
• Provides individualised feedback

*Ultimate research question:* Under which conditions will learners be more motivated and achieve more?
“Call to arms”

DynaLearn is always looking for partners that want to:

• Use DynaLearn in their educational practice.
• Perform their own research using DynaLearn.
• Contribute to enhancing Science Education in any other way.

http://www.DynaLearn.eu
Administrative summary

- Project number: 231526
- Project acronym and title: DynaLearn - Engaging and informed tools for learning conceptual system knowledge
- Starting date: February 1st, 2009
- Duration in months: 36 PMs
- Call (part) identifier: FP7-ICT-2007-3
- Activity code(s) most relevant to the topic: ICT-2007.4.3: Digital libraries and technology-enhanced learning
- Keywords: Conceptual knowledge, Science education, Diagrammatic, representations, Ontology mapping, Virtual characters.

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