Overview

• Learning and simulations
• Research questions
  • Diagnosing learning behaviour
  • Curriculum planning
  • Explanation (incl. visualisation) (*brief*)
• Concluding remarks
• Applications and References (*brief*)
Explanation!

How to generate explanatory discourse?

• ‘Canned text’ and templates are inflexible

• ‘Translating the code’ is unnatural

So, how to generate explanatory discourse automatically?

• generic, possible to re-use

• flexible, based on student’s needs
Explanation!

Separating the **WHAT** (*content*) from the **HOW** (*form*)

**WHAT**: curriculum planning and didactic goals

- Different levels of time:
  - Over sessions, during one session, one discourse event

- Different levels of content:
  - Curricula, Topics, Issues, Concepts, Rules, Facts

**HOW**: graphics, text, VR, animations, etc.
Overview

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Curriculum Planning & Didactic Goals

The Problem

...dividing the subject matter into pieces (parts) that can be dealt with by learners ...

Issues

• What parts should be singled out?
  (According to what criteria ?)

• Where to start ?
  (Simple to complex, Conditional, etc.?)

• How to proceed?
  (According to what criteria?)
Example: Arithmetic

• What is more difficult? And Why?

\[
\begin{array}{ccc}
5 & 5 & 5 \\
4 + & 4 - & 4 x
\end{array}
\]

\[
\begin{array}{ccc}
5 & 5 & 5 \\
4 + & 4 - & 4 x
\end{array}
\]

\[
\begin{array}{ccc}
5 & 5 & 5 \\
4 4 + & 4 4 - & 4 4 x
\end{array}
\]

E.g. • number of inference steps (borrow is more difficult) • memory load • the number as such (9 more difficult than 2)
Didactic Principles: examples from literature

- from simple to complex / from easy to difficult
- from known to unknown
- from general to specific (OR: from specific to general)
- alternative viewpoints
- opportunistic
- structure versus behaviour
- on the basis of dependencies (conditional foreknowledge)

Research question:

What are the dimensions that define the space of ‘subject matter sequencing’?
Ideas on model dimensions (a selection)

• Genetic Graph
  (Goldstein, 1979)

• Causal Model Progression
  (White & Frederiksen, 1990)

• Compositional Modeling
  (Falkenhainer & Forbus, 1991)

• Models for Ecology
  (Salles & Bredeweg, 1997 & in press)
Genetic Graph *(Goldstein, 1979)*

Domain knowledge:
Logical & probabilistic reasoning
(*represented as a set of rules*)

Definition:
A knowledge representation consisting of individual pieces of knowledge which are connected by learner-oriented links representing the evolutionary nature of knowledge.

Dimensions:
- Refinement
- Analogy
- Generalisation / Specialisation
Causal Model Progression (White & Frederiksen, 1990)

Domain knowledge:

   Diagnosing electronic circuits

Definition:

   ... To start with a simplified (simple) world (model) and to have a coach progressively add new dimensions of complexity that require an increasing mastery of expertise (skills)…

Dimensions:

   • Perspective
   • Order
   • Elaboration
Causal Model Progression (Dimensions & Learning)

- **Type (perspective)**
  
  e.g.: $V = I \times R$ versus electrons

- **Order**
  
  zero order (on/off)
  
  first order (changes)
  
  second order (‘relative’ changes...)

- **Elaboration**
  
  more intermediate dependencies

**Dimensions**

- Within the current model (e.g.: *solve a diagnostic problem*)
- With respect to next model (level)
  
  - unsolvable problems (*need for more complex model*)
  
  - explanation on differences between models
Causal Model Progression *(Statements on Learning)*

‘... as a student learns her model becomes **elaborated** - changes in degree - by including further constraints. More radical transitions take place when a new **order** or a new **type** is introduced…’

‘...deep understanding does not consist of a single model, but is characterized by the coexistence of a set of complementary models that vary along the dimensions…’

**Related work: Sime (ITS’96 / AIED’95)**

Using multiple models/ perspectives

*(Cognitive Flexibility approach)*
Compositional Modeling (Falkenhainer & Forbus,’91)

A more technical concern: getting the simulation right!

Example: Which quantities to use?

• temperature
• heat capacity
• materials (container, liquid)
• thickness
• boil point, freezing point
• turbulence
• with of outlet
• forces between molecules

• … (many more)
Compositional Modeling (Domain example)

Steam-powered propulsion plant

Query: How does an increase in the furnace fuel/air ratio affect the amount of steam flowing in the superheater?
Compositional Modeling (Model dimensions)

**Simplifying assumptions**

- **Perspective / Ontology** *(The view taken on the physical system)*
- **Granularity / Grain-size** *(How much structural detail to include?)*
- **Approximation / Abstraction** *(What behaviours to take into account?)*

**Operating assumptions**

- **Boundaries / constants / starting values**
  *(compares to “Experimental frame”)*

In order to do:  • Query analysis
  • Object expansion
  • Candidate completion
  • Candidate evaluation and selection
Models for Ecology *(Salles & Bredeweg, 1997 & in press)*

Fire management in the Brazilian Cerrado
Models for Ecology (Model fragments 1: views)

about multiple entities...

Cerrado Sensu Lato
  - Campo Limpo
    - C.L with less grass
  - Campo Sujo
    - C.S. with no Trees
  - Campo Cerrado
    - C.S. with Trees
  - Typical Campo Cerrado
    - Minimum size
    - Small size
    - Medium size
    - Large size
  - Maximum size
  - No population
  - Increasing population
  - Decreasing population
  - Steady population
  - Extinct population

about single entities...

Cerrado
  - Cerradoao
    - Climax Cerradoao
  - Open Cerradoao
  - Typical Campo Cerrado
    - C.L with less grass
  - C.S. with no Trees
  - C.S. with Trees
  - Typical Campo Cerrado
    - Minimum size
    - Small size
    - Medium size
    - Large size
  - Maximum size
  - No population
  - Increasing population
  - Decreasing population
  - Steady population
  - Extinct population

Existing population

Plant type view
  - Herbaceous
  - Grass
  - Shrub
  - Tree

Population size view

Direction of change view
Models for Ecology (Model fragments 2: processes)

processes concerning single and multiple entities...
Models for Ecology (Ordering by Model Fragment type - 1)
Models for Ecology *(Ordering by Model Fragment type - 2)*

- **P-mf**
  - **A-mf**
    - **S-mf**
      - **S-mf**
        - **S-mf**
          - **S-mf**
            - **C-mf**
              - **P-mf**

- **P-mf**
  - **A-mf**
    - **S-mf**
      - **S-mf**
        - **S-mf**
          - **C-mf**
            - **P-mf**

- **Elaboration**
- **Order**
- **Conditional**
- **Isa**
- **Effects**
- **Same Entities or Features**
- **Part of**
- **Analogy**
Curriculum planning *(summary)*

How to carve up the subject matter into partial simulation models which are ‘digestible portions’ for a learner?

Each model should be:

- Technically sufficient
- Match students knowledge state
- Progress from simple to complex

**Issue:**

Dimensions for model complexity
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Principles of Explanation

*Based on Winkels (1992) and Moore (1996)*

- **Coherence**: explanations should be structured
- **Sensitivity**: to user’s knowledge, goals, task, prior dialogue
- **Signaling**: give overview, point out relationships
- **Responsiveness**: offer feedback and further explanations
- **Flexibility**: multiple ways of achieving communicative goal
Explanation: Skeletal Strategy Structures

*Implements coaching principles, together with refinement rules*

A general strategy consists of six parts:

- Announcement
- Context
- New Information
- Consolidation
- Evaluation
- Closing
Explanation: HOW - Visualization

Basic idea

Representation: ‘Analogical’ versus ‘Propositional’

Advantages of analogical

• explicit representation (*more direct*)

• effective control (*reasoning process*)

• more natural/understandable (*to humans*)
Explanation: HOW - Example

Manard's plot of Napoleon's Russian Campaign, 1813
Explanation: HOW - Example

Fire management in the Brazilian Cerrado

Showing only ‘number_of’ grass, shrub, and tree, and not the other ‘40 quantities’...
Explanation: HOW - Example

Visual languages

• Vocabulary of graphical symbols

• Diagrammatic rules

• Expressiveness - *all facts (and only all facts)*

• Effectiveness - *easy of expressing / perceiving*

• Emergent properties
Visualization

A very different perspective...?
Concluding remarks

• Simulation models are getting more articulate, but we are not there yet…

• Teaching functions are being addressed,
  • Interpretation of learner behaviour: well understood, but...
  • Curriculum planning: many ideas, no integration yet...
  • Structured explanation / visualisation: open area…

Not addressed in this talk, but interesting:

• WWW: collaborative learning/interacting with simulations
• Learning by building models
Applications and Case studies

- **Cycle pad**
  
  http://www.qrg.ils.nwu.edu/software/software.htm

- **Thinker tools**
  
  http://thinkertools.berkeley.edu:7019/index.html

- **Auto Steve**
  
  http://www.isi.edu/isd/VET/steve-demo.html

- **SIMQUEST**
  
  http://www.simquest.to.utwente.nl/simquest/

*Older work…*

- **ITSIE**
  
  (Intelligent Training Systems in Industrial Environments, finished end 1993)
  
References (1)

General

Artificial Intelligence and Tutoring Systems, E. Wenger, Morgan Kaufmann, 1987. (Summary of older work: e.g. Scholar, Why, Wusor, Sophie, Steamer).


Recent workshop at ECAI-1998 on MBR and ILE (for contributions see: http://www.swi.psy.uva.nl/usr/bert/ecai-ws.html)

References (2)

Explanation


Interactive simulations

References (3)

**Diagnosing Learner behaviour**


**Model dimensions**


References (4)

**Visualisation**


The sage visualization group (CMU/USA)
http://www.cs.cmu.edu/~sage/sample.html

**Ecology and QR**