Supporting Conceptual Modeling of Dynamic Systems

Jochem Liem
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Exercise

- Scenario: Atmospheric CO\textsuperscript{2} in stabilizes in 2100
- Sketch:
  - CO\textsuperscript{2} emissions
  - net removal
Failure is typical

- 84% of graduate students at MIT incorrect
- Current science and math education insufficient!
- Similar problems difficult for general public
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Conceptual Simulation Models

- Learning by modeling
  - Causes of change (I+/I-)
  - Propagation of change (P+/P-)
Applicable to many domains
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Benefits of conceptual models

• Conceptual representation (even for values)
  – Qualitative distinct values (0\textsuperscript{p}, clean, critical\textsuperscript{p}, toxic)
  – To which systems do theories apply?
  – Under which conditions?

• Simulation: Testing your ideas

• Direct & indirect causality
  – Cause / Propagation / Feedback

• Re-occurring patterns
  – Bathtub = Atmospheric CO\textsubscript{2} = Bank account = Population
Three research contributions

1. Conceptual modeling in secondary education
   • How can *learning by modeling* be made easier?

2. Method to grade conceptual models
   • What is important in a conceptual model?
   • How should models be graded?

3. Interoperability in interactive learning environment
   • How can software components *reuse* model information?
1. Learning spaces

- 6 learning spaces
  - Modeling and simulation
  - Progressively more complete subsets of full language

- Successfully evaluated
  - Usable in secondary school
  - Allows learning of domain knowledge
  - Reoccurring patterns
2. Improvement & grading

• Guidelines for modeling
  – What is a good model?
  – Ways to detect errors and correct them.

• Evaluation
  – Allows model grade to be derived.
  – Grades correspond to intuition of teachers.
3. Reusable Models

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Conclusions

• New: learning by conceptual modeling!
• Research allows:
  – Conceptual modeling in high school
  – Grading of conceptual models
  – Teaching of better modeling
  – Support via virtual characters