FUTURE DEVELOPMENTS IN EDUCATIONAL SCIENCE AND TECHNOLOGY ENHANCED LEARNING

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THE NETHERLANDS
OVERVIEW OF THE PRESENTATION

- Developments in education and related ICT developments
- Focus on (collaborative) learning with simulations
- Cognitive aspects of inquiry learning
- How to create educationally well designed simulations?
- Open questions and future directions
DEVELOPMENTS IN TECHNOLOGY ENHANCED LEARNING

- Constructive learning
  - Inquiry learning
  - Constructionism
  - Computer simulations/games
  - Modelling environments

- Collaborative learning
  - Shared representations
  - Chats
  - Scripts

- Situated learning
  - Realistic topics
  - Simulators (e.g., medicine)
EXAMPLES OF OUR WORK IN TWENTE

- SimQuest
- Co-Lab
- KMQuest
- ZAP
- SCY

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WHY SHOULD LEARNING WITH SIMULATIONS WORK?

- Inquiry learning; following a scientific investigation cycle (e.g., de Jong 2006, many others)
- Multiple representations (Ainsworth, 2006)
- Interactive visualizations (Lindgren & Schwartz, 2009)
- Should lead to better integrated, more insightful, and more intuitive knowledge
AN EXAMPLE SIMULATION

\[ M = F \times a = 150 \text{ kN} \times 17.3 \text{ m} = 2598 \text{ kNm} \]

<table>
<thead>
<tr>
<th>Exo Nr</th>
<th>beta</th>
<th>a</th>
<th>alpha</th>
<th>F</th>
<th>i</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>30.0</td>
<td>17.3</td>
<td>120.0</td>
<td>150.0</td>
<td>20.0</td>
<td>2598.1</td>
</tr>
</tbody>
</table>

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BUT IT DOESN’T WORK JUST LIKE THAT!
SCAFFOLDING IS NEEDED

- Orientation
- Hypothesis generation
- Experimentation
- Concluding
- Planning
- Monitoring
- Reflection

- Connecting representations
- Translating between representations
- Support to contrast cases
SIMULATION BASED LEARNING COMPARED TO TRADITIONAL, EXPOSITORY, INSTRUCTION

- If well designed, so scaffolds included, simulation show an advantage over expository instruction (large scale evaluations)
  - Shute & Glaser, 1990: Smithtown
  - White & Frederiksen, 1998: ThinkerTools
  - Hickey, Kindfield, Horwitz, & Christie, 2003: GenScope
  - de Jong, Hendrikse, & van der Meij, in press: SimQuest Math

- Effects on conceptual (intuitive) knowledge
Students in simulation based environments score better than or at the same level as students in a real laboratory

- Chang, Chen, Lin, & Sung, 2008
- Klahr, Triona, & Williams, 2007
- Van Klink, Wilhelm, & Lazonder, submitted

Students learning in a sequence of simulation and real laboratory outperform the simulation and/or laboratory.

- Zacharia & Anderson, 2003
- Zacharia, 2007
- Jaakkola & Nurmi, 2008
- Zacharia, Olympiou, & Papaevripidou, 2008

Effects on conceptual knowledge
THE EFFECTIVENESS OF INQUIRY LEARNING

Situation: each runner has a T-shirt with a different colour: red, green, pink, or yellow. What is the probability (p) of the following score:

1. red
2. green
3. pink
4. yellow

Answer:

\[ p = \frac{1}{120} \]
A COMPARISON OF INSTRUCTIONAL STRATEGIES

- Performance (different types of knowledge):
  - $\text{EL > IL > (HL = OL)}$
  - For far transfer IL scores higher

- Efficiency:
  - $\text{HL > (IL = OL) > EL}$

HOW TO DESIGN SUPPORTIVE INQUIRY ENVIRONMENTS?

PROBLEMS IN INQUIRY LEARNING

- Poor hypotheses
- Ineffective experiments
- Engineering approach
- Mistakes in data interpretation
- No planning and monitoring (floundering)
- etc.
SCAFFOLDS

- Assignments
- Explanations
- Model sequencing
- Monitoring facilities
- Hypothesis scratchpad

- Prompts
- Hints
- Data interpreters
- Etc. etc.

SCAFFOLDS AND COLLABORATIVE INQUIRY

What was done?

Which variables?
Which hypothesis?
Which variables?
What results?
Which conclusion?

What next?

Orientation
Planning
Monitoring

Hypothesis
Experiment
Conclusion

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Differences in opinion should lead to discussion and progress in learning

- Okada and Simon (1997)

Focus on hypothesis generation

SUPPORTING COLLABORATIVE INQUIRY

- Domain Kinematics (velocity, acceleration etc.);
- SimQuest simulation
- Three conditions
- Shared proposition table
- Shared hypothesis scratchpad
- Control - Without scaffolds
- Pre-post test of different kinds (definitional, intuitive, propositional)
- Qualitative analysis of chats
- 66 students (±15 years old); heterogeneous dyads

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SHARED PROPOSITION LIST

Proposition list

Learner 1

Learner 2

Start relevant experiment

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PROPPOSITION SCRATCHPAD

The scratchpad contains a logical expression:

```
if m_total increases
then V decreases
if also
```

The proposition needs testing. The table below shows the propositions and their truth values:

<table>
<thead>
<tr>
<th>Proposition</th>
<th>Answer</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>If m_total increases, then V decreases</td>
<td>true</td>
<td>untested</td>
</tr>
<tr>
<td>If drive decreases fast, then V decreases</td>
<td>true</td>
<td>tested</td>
</tr>
</tbody>
</table>
RESULTS (IN A NUTSHELL)

- Shared proposition table condition:
  - significantly higher learning gains than shared hypothesis scratchpad and control
- Shared proposition table condition:
  - discussed significantly more unique propositions (on which they disagreed)
  - explored a larger proportion of the simulated domain
- A positive correlation between number of unique propositions and test scores was found
HOW TO COME FROM COGNITION TO TEL SYSTEMS?

INQUIRY PROCESSES,

- Basic research
  - Experimental studies (smaller (n = approx 25 per condition) or larger number (n = 100+ per condition) of students)
  - Small scale, qualitative, studies
  - In realistic situations

- Usability studies
  - (Larger scale) applications

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TECHNIQUES USED

- Experimental manipulations: pre-test post-test control group design
  - Knowledge tests, questionnaires
  - Process analysis
    - Thinking aloud protocols
    - Log-file analysis
    - Chat analysis
    - Neuropsychological techniques
Question: How do students process different representations?

- 18 subjects, within subject design
- Four representations: Concrete, Formula, Table, Graph
- No task and task conditions (identify values)

EEG: Event related potentials

\[ M = F \times a = 200 \text{ N} \times 200 \text{ mm} = 40000 \text{ Nmm} \]
RESULTS

- Behavioral data
  - Accuracy: picture > formula, graph, table
  - Reaction time: formula < graph, picture < table
- ERP
  - No task condition
    - P1 (sensory analysis): picture > formula
    - P3 (cognitive processing): picture > formula
  - Task condition
    - P3 (cognitive processing): graph > formula
BUT THERE IS MORE

- **General considerations**
  - Interactive
  - Fast – Immediate - Always
  - Dynamic
  - Multi-faceted (not boring)
  - Socially entrenched

- **Practical considerations**
  - The length of a lesson
  - Examination requirements
  - Technical constraints
  - The skills of the teacher
  - Etc. etc.
RESEARCH AGENDA

- The role of “products” to design
  - Models (qualitative and quantitative)
  - Concept maps
  - Assignments
- The role of representations
  - Affordances of different types of representations (textual, arithmetical, graphical)
  - Multiple representations
- Collaboration and inquiry
  - Interaction between task related activities and communicative activities
- Process analysis/Adaptive environments/Individual differences
  - Interaction data
  - Neuropsychological data
  - Assessment of models
  - Educational data mining

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CONCLUSIONS

- TEL is a combination of
  - Cognition
  - Technology
  - Educational science
- Doing “in vivo” research has many challenges
- But we are the edge of exiting developments!

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