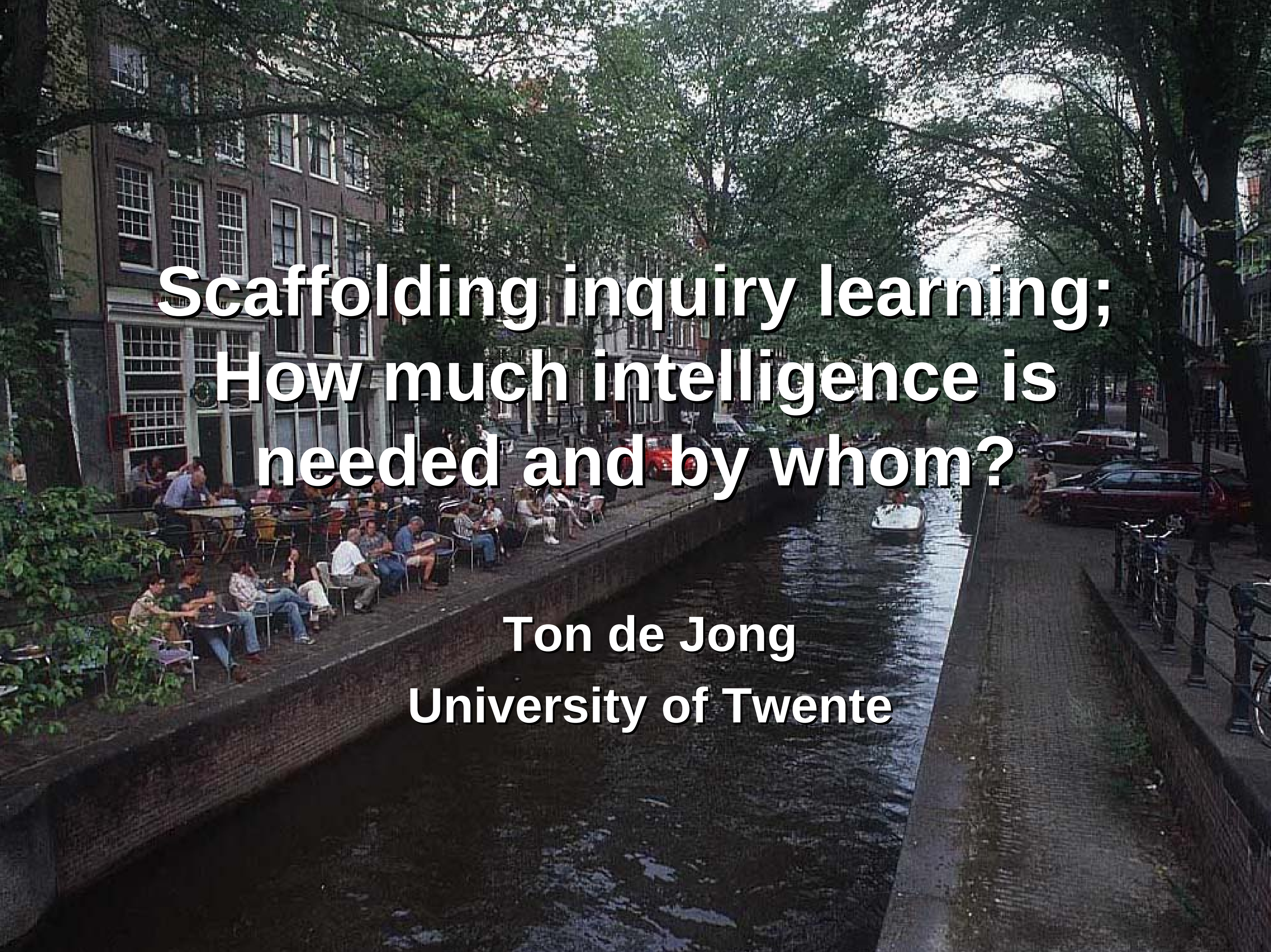


Scaffolding inquiry learning; How much intelligence is needed and by whom?

Ton de Jong
University of Twente

Topics

- Inquiry (scientific discovery) learning
- Computer simulation based learning environments
- How to make *simulation based inquiry* learning successful?
  - Scaffolds
  - Conditions
- Is intelligence needed?

Inquiry Learning

Inquiry is an approach to learning that involves a process of exploration, that leads to asking questions and making discoveries in the search for new understandings

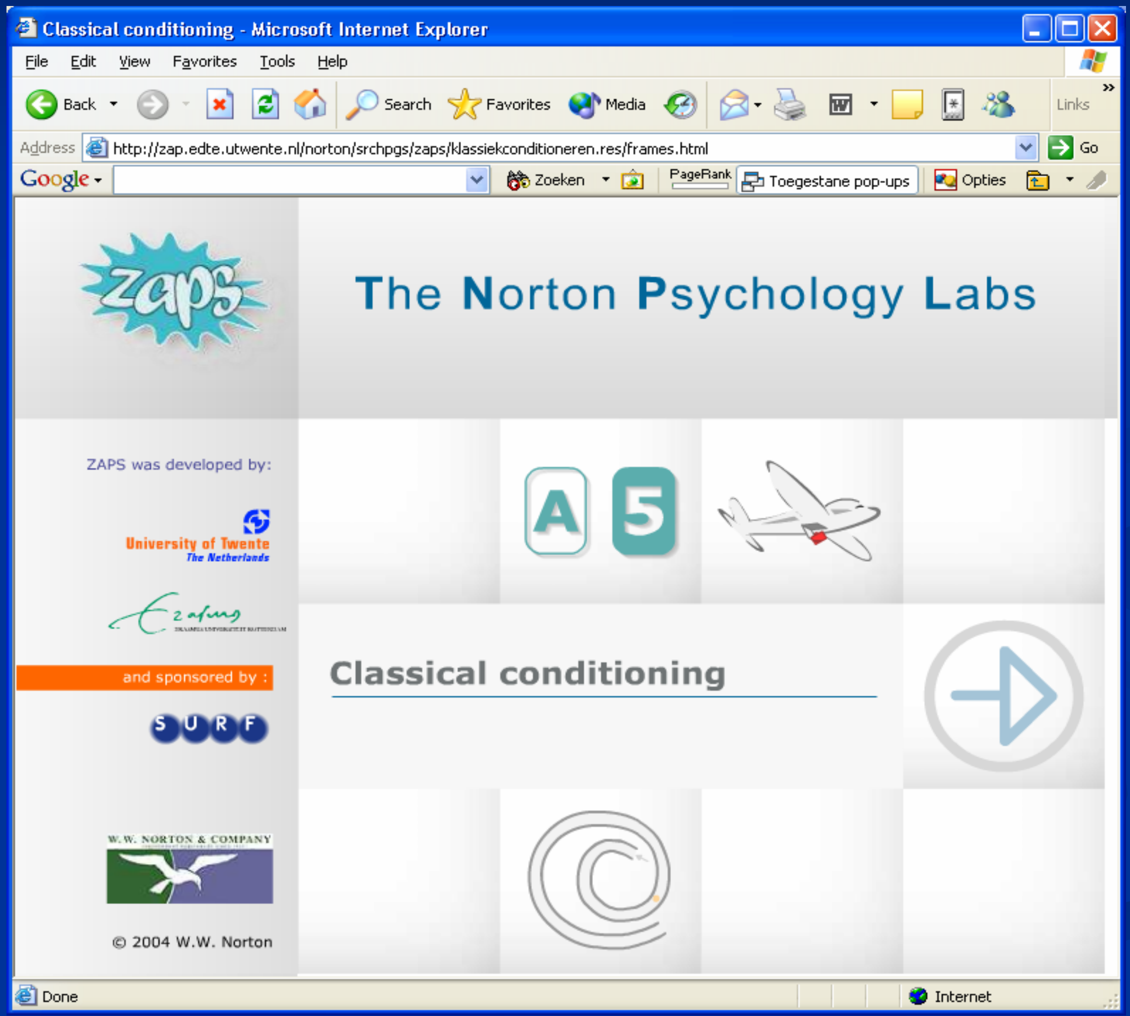
Based on "Foundations", Vol, 2, NSF, 2000

Technology enhanced inquiry learning

- TEL environments
  - Simulations, games, adventures
  - Remote labs
  - Data sets
  - Hypermedia
- Simulations
  - Model of a system or a process
  - Students have to infer this model
  - They change values of input variables and observe values of output variables

An example simulation SimQuest

An example ZAP simulation



S: Norton Psychology Labs - Microsoft Internet Explorer

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The Norton Psychology Labs

ABOUT THE ZAPS | TEACHING WITH ZAPS

ZAPS DEMOS

Demo 1:
Simon Effect

Demo 2:
Wason Selection Task

Demo 3:
Big Five

Demo 4:
Ponzo Illusion

Demo 5:
Cognitive Dissonance

✔ Complete ZAPS List

What are ZAPS: The Norton Psychology Labs?

Want to expose your students to the scientific process but don't have time for a lab? The solution is ZAPS!

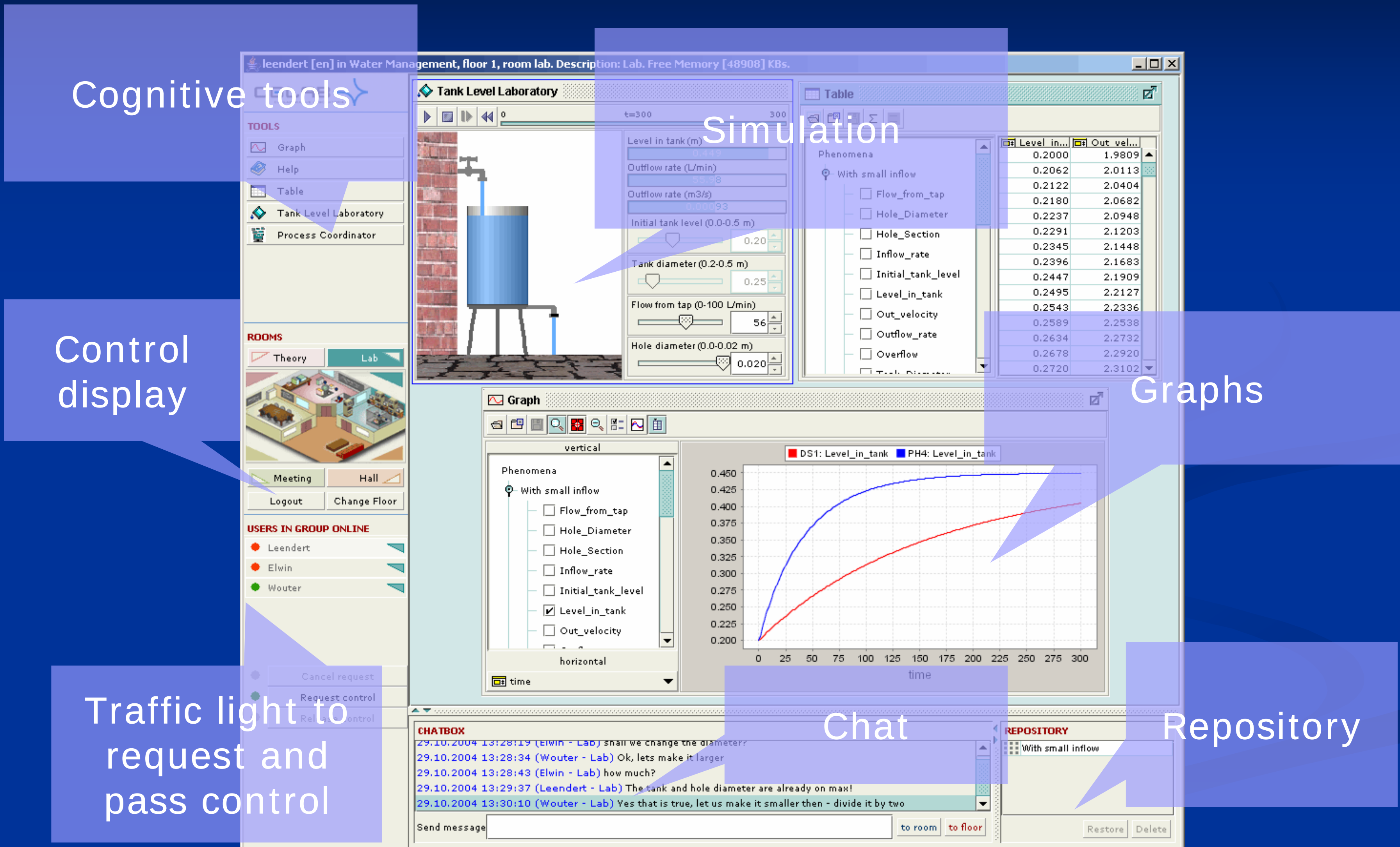
$28 stand-alone! $10 with a Norton book!

What are ZAPS: The Norton Psychology Labs?

Perfect for introductory psychology or cognition courses, **ZAPS: The Norton Psychology Labs** is a set of 45 interactive computer experiments that allow students to experience psychological phenomena and classical experiments in exciting and interactive online environment. Each ZAP is designed to be completed in 15 to 30 minutes.

ZAPS cover a wide range of topics in psychology. There are ZAPS that cover biological and physiological phenomena, such as the gate-control theory of pain, and ZAPS that cover findings from social

Co-Lab



Cognitive tools
Simulation
Control display
Graphs
Traffic light to request and pass control
Chat
Repository
leendert [en] in Water Management, floor 1, room lab. Description: Lab. Free Memory [48908] KBs.
TOOLS
Graph
Help
Table
Tank Level Laboratory
Process Coordinator
ROOMS
Theory
Lab
Meeting
Hall
Logout
Change Floor
USERS IN GROUP ONLINE
Leendert
Elwin
Wouter
Cancel request
Request control
Tank Level Laboratory
Level in tank (m)
Outflow rate (L/min)
Outflow rate (m3/s)
Initial tank level (0.0-0.5 m)
Tank diameter (0.2-0.5 m)
Flow from tap (0-100 L/min)
Hole diameter (0.0-0.02 m)
Table
Phenomena
With small inflow
Flow_from_tap
Hole_Diameter
Hole_Section
Inflow_rate
Initial_tank_level
Level_in_tank
Out_velocity
Outflow_rate
Overflow
Graph
vertical
horizontal
time
DS1: Level_in_tank
PH4: Level_in_tank
CHATBOX
29.10.2004 13:28:34 (Wouter - Lab) Ok, lets make it larger
29.10.2004 13:28:43 (Elwin - Lab) how much?
29.10.2004 13:29:37 (Leendert - Lab) The tank and hole diameter are already on max!
29.10.2004 13:30:10 (Wouter - Lab) Yes that is true, let us make it smaller then - divide it by two
Send message
to room
to floor
REPOSITORY
With small inflow
Restore
Delete

Mayer

Should there be a three-strikes rule against pure discovery learning? (American Psychologist, 2004)

- Overview of studies in ‘problem solving’, ‘conservation strategies’, and ‘programming’
- Pure discovery learning is not effective because learners may not be confronted with the to-be-learned material
- Guided discovery is more effective than pure discovery learning or expository teaching

Klahr and Nigam

The equivalence of learning paths in early science instruction: effects of direct instruction and discovery learning
(*Psychological Science, 2004)*

- Students experimented with a ball rolling from a wooden ramp, one group received no support at all, in the other group an experimenter gave examples of good and poor experiments, explained differences between experiments, etc.
- The ‘support’ group outperformed the ‘pure discovery’ group on use of CVS strategy (but still 23% of the kids in the pure discovery group learned CVS)
- On a later test there was no differences between kids having learned through ‘direct instruction’ and kids having learned by ‘pure discovery’

Conclusions so far

- Pure discovery does not work
- Support/scaffolds should be present to make inquiry productive

- Learning goals can be very different
- Domains can be very different
- Students can be very different

- Definitions (discovery, inquiry, direct instruction) can be very different
- Therefore, we need a better view on what constitutes inquiry learning

Inquiry processes

Transformative processes

- Orientation
- Hypothesis generation
- Experimentation
  - Experiment design
  - Prediction
  - Data interpretation
- Conclusion

Regulative processes

- Planning
- Monitoring

Problems in discovery

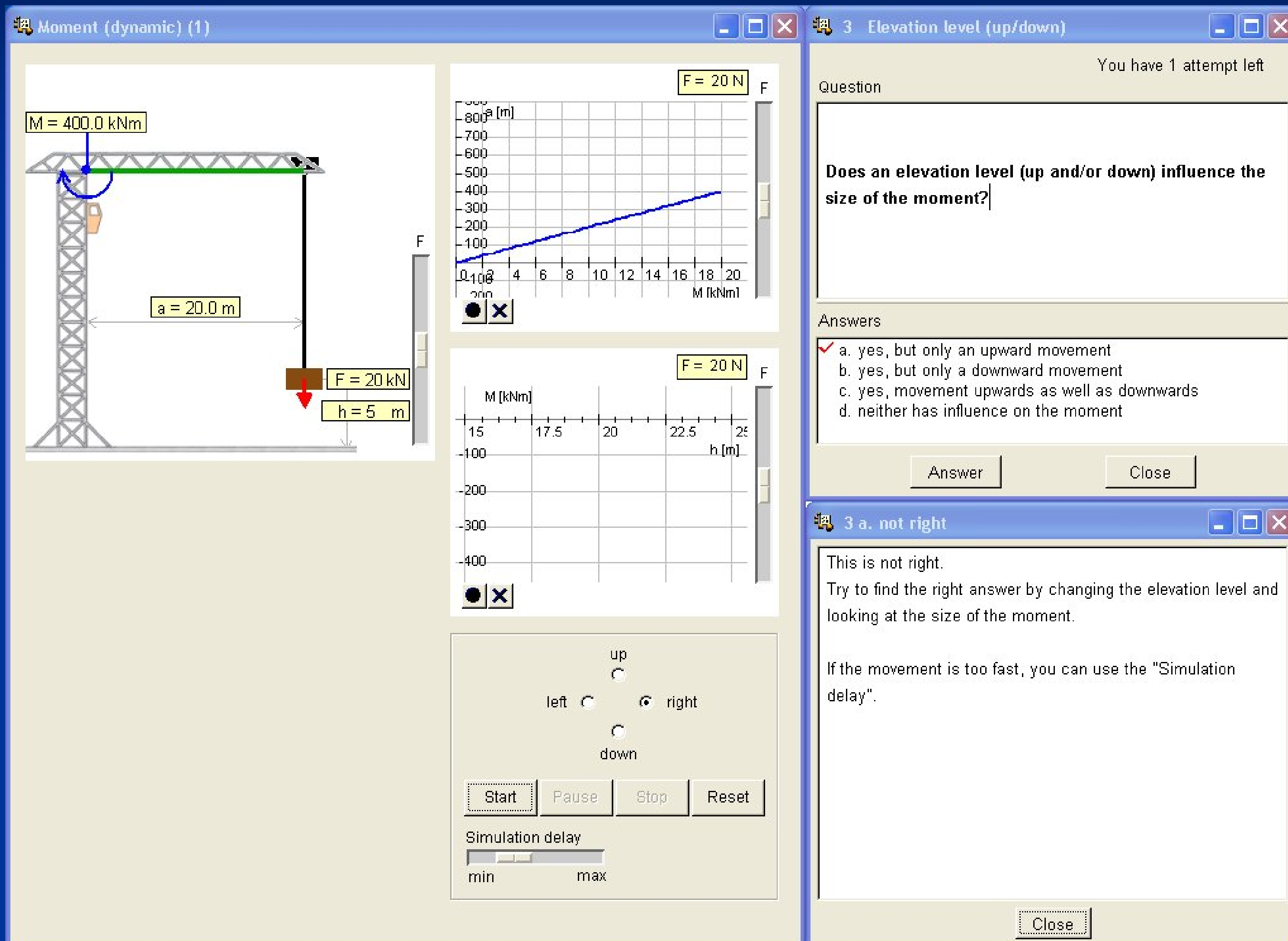
- Poor hypotheses
- Ineffective experiments
- Engineering approach
- Mistakes in data interpretation
- No planning and monitoring (floundering)
- etc.

Scaffolds

- Assignments
- Explanations
- Model sequencing
- Monitoring facilities
- Hypothesis scratchpad
- Prompts
- Data interpreters
- Etc. etc.

2004 special issue of the JLS
2004 LEA book on science environments
by Linn, Bell, and Davis

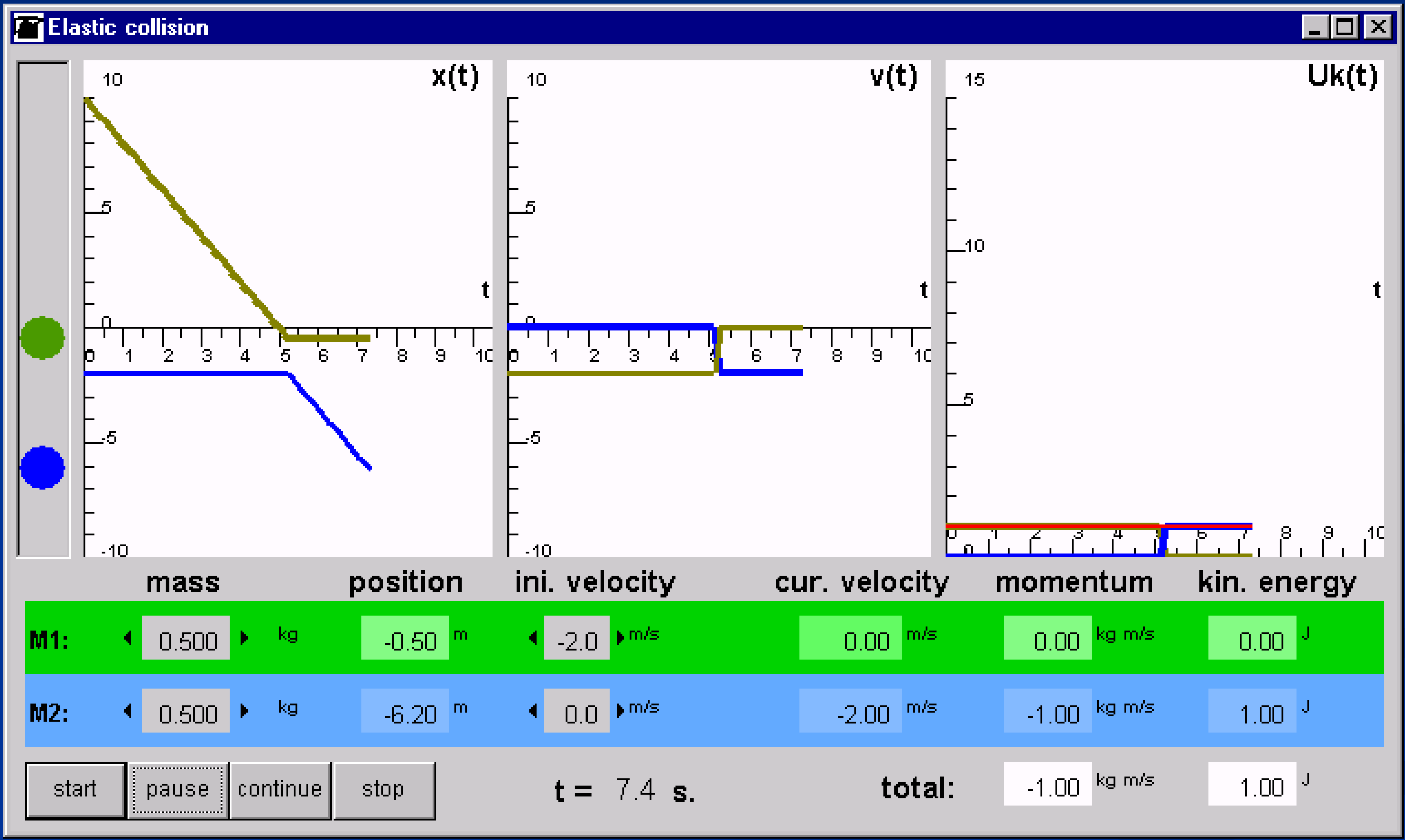
Example of an assignment



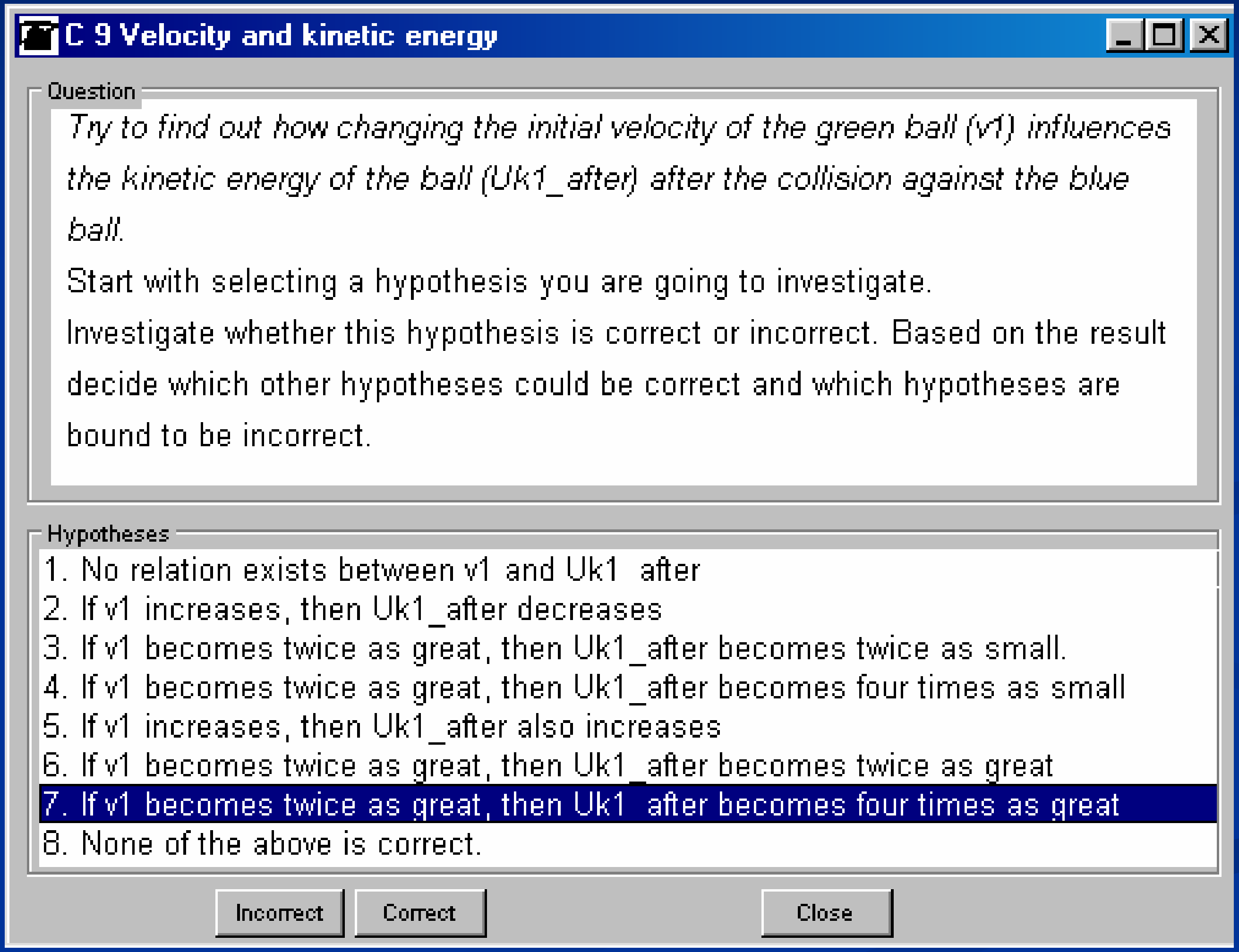
Results of scaffolding

- Structuring the environment helps
  - Assignments
  - Ready made hypotheses
  - Overall structures
- Providing background information is necessary
- Model progression is not always helpful
- *Adaptive scaffolding*
- *Scaffolded collaboration*

Adaptive scaffolding
Simulation on collisions

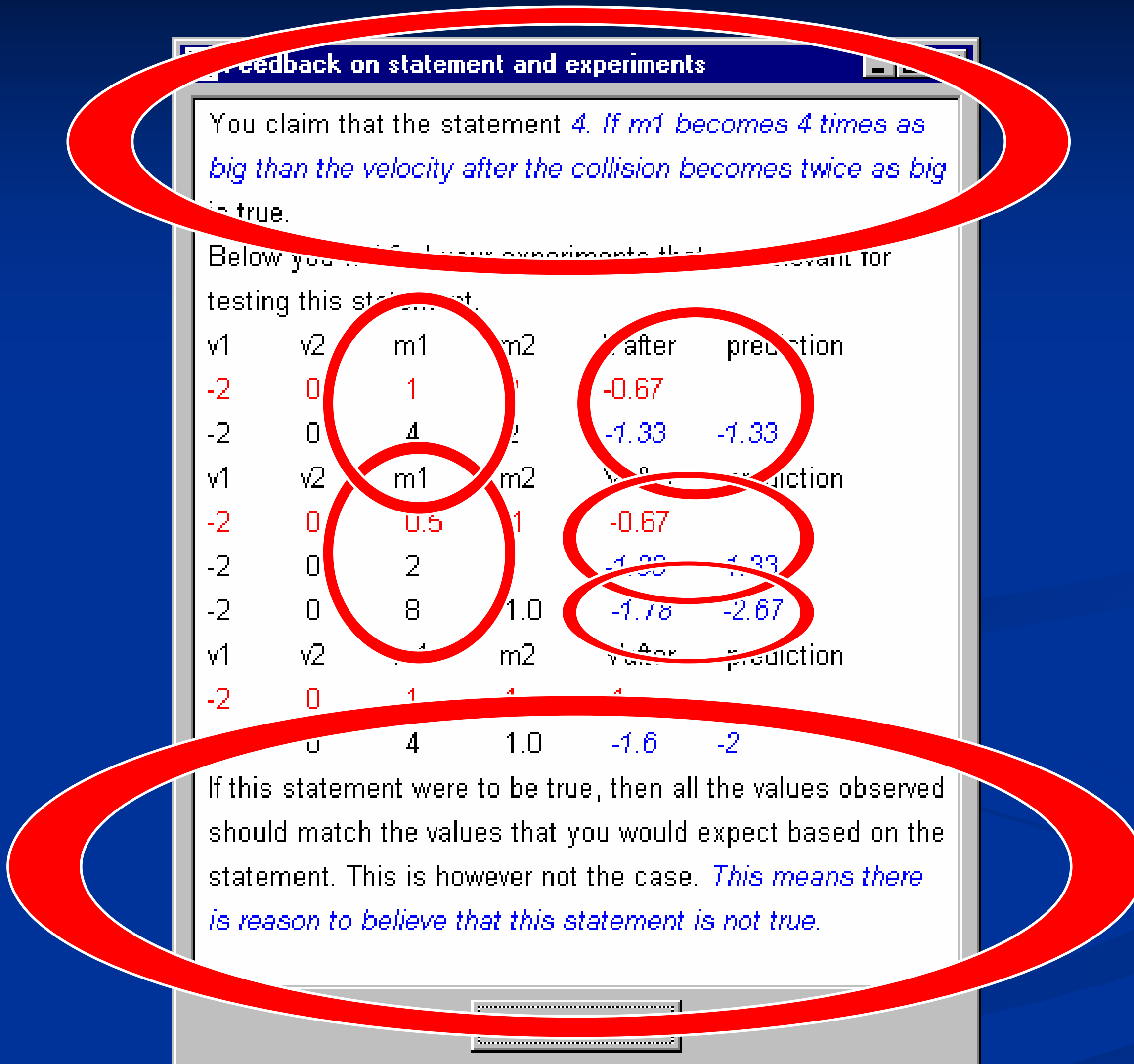


The assignments used



Feedback generation

- Student receives an assignment
- Student selects a hypothesis:
  - “a greater mass m1 has no influence on the velocity after the collision”
- Student performs experiments
- Student decides if hypothesis is supported
- System generates feedback
  - selects relevant experiments
  - predicts values dependent variables from the hypothesis
  - compares predicted values with actual values
  - composes feedback


eedback on statement and experiments
You claim that the statement 4. If m1 becomes 4 times as
big than the velocity after the collision becomes twice as big
true.
testing this st
v1 v2 m1 m2 after
-2 0 1 -0.67
-2 0 4 -1.33 -1.33
v1 v2 m1 m2
-2 0 0.5 1 -0.67
-2 0 2
-2 0 8 1.0 -1.78 -2.67
v1 v2 m2
-2 0 1
4 1.0 -1.6 -2
If this statement were to be true, then all the values observed
should match the values that you would expect based on the
statement. This is however not the case. This means there
is reason to believe that this statement is not true.

Outcomes of a study

Standard feedback

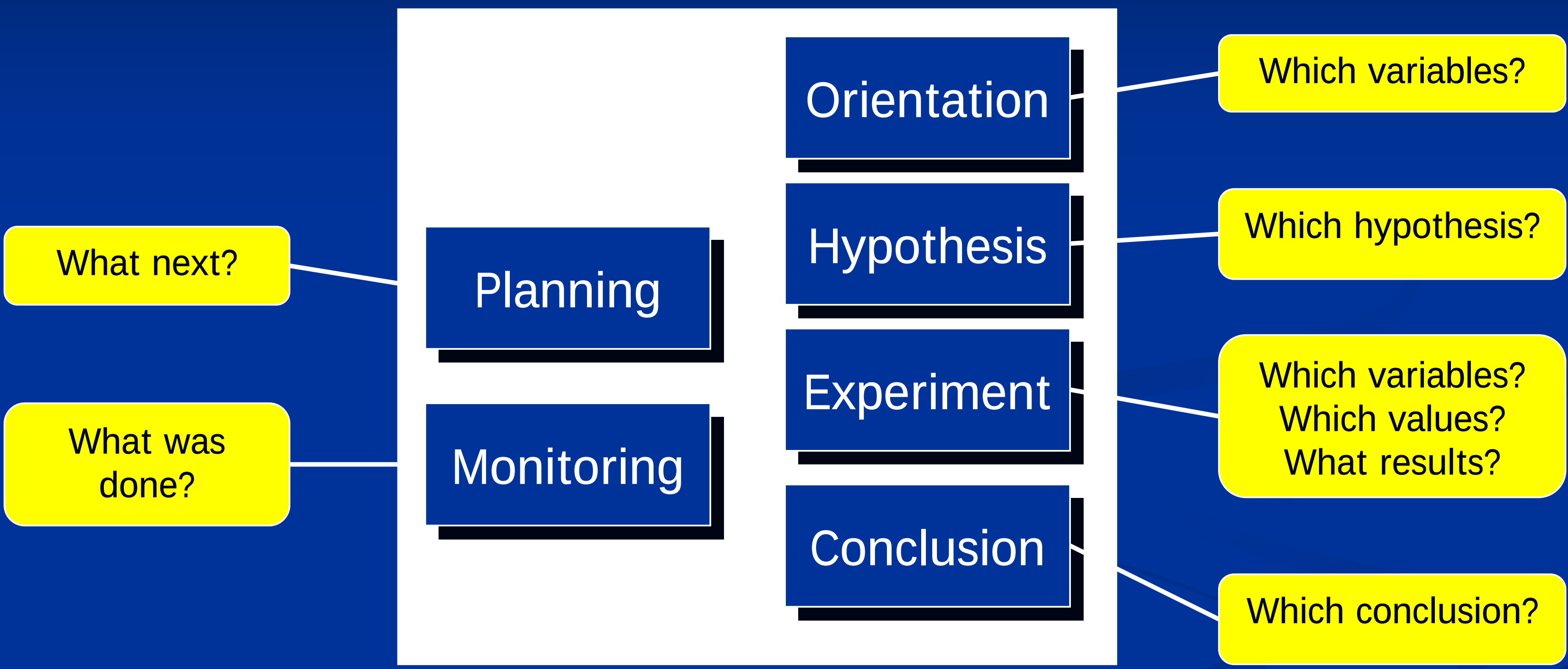
- Knowledge gain
- More assignments

Adaptive feedback

- Knowledge gain
- More time on an assignment
- More experiments for an assignment
- More relevant experiments
- More unique experiments

Veermans et al. IJSE (in press)

Scaffolds and collaboration



Collaborative discovery

- Differences in opinion should lead to discussion and progress in learning

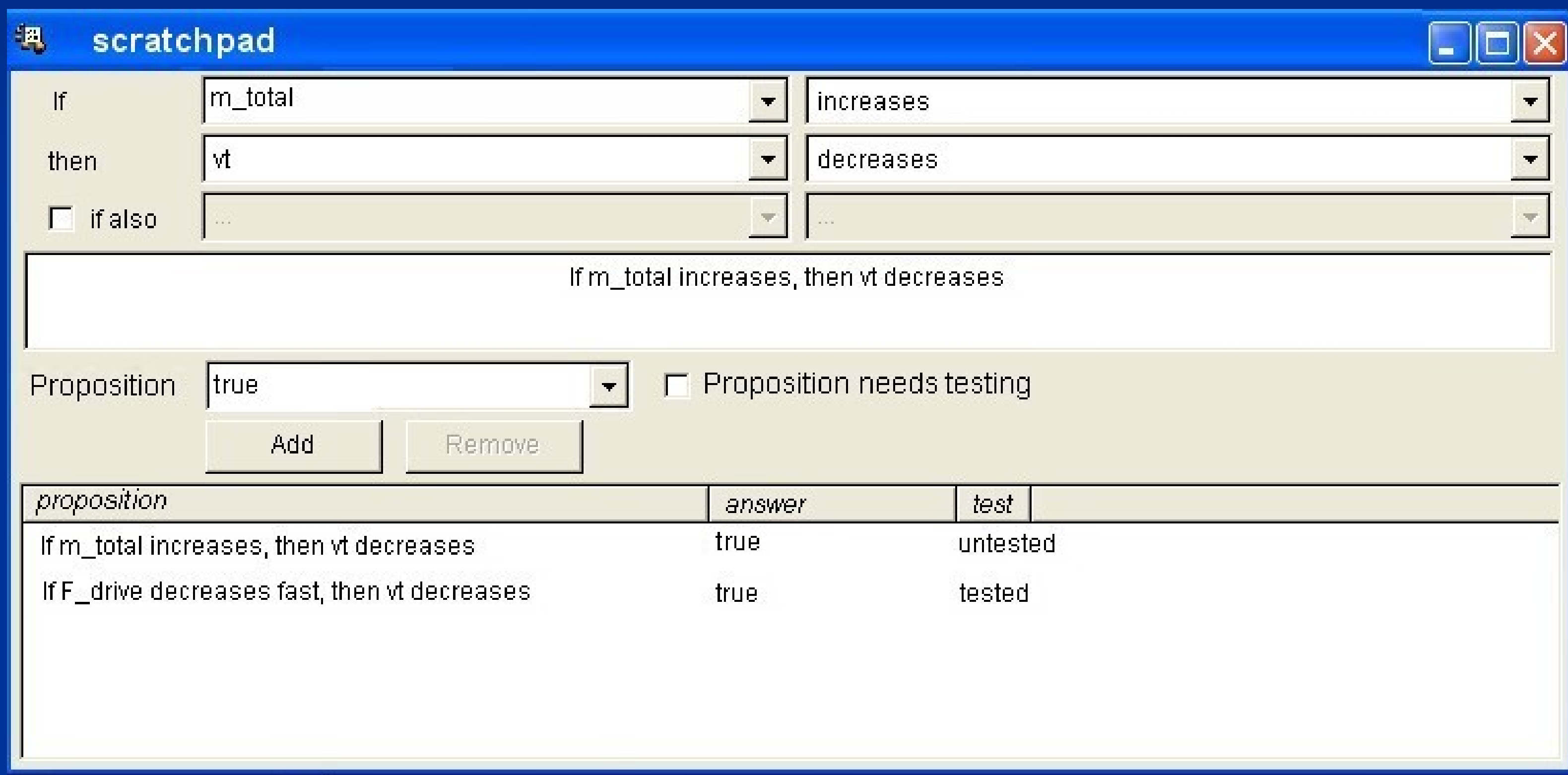
- Conversation of homogeneous dyads focused on orientation processes
- Heterogeneous dyads made more utterances related to hypothesis generation

Gijlers & de Jong, JRST (2005)

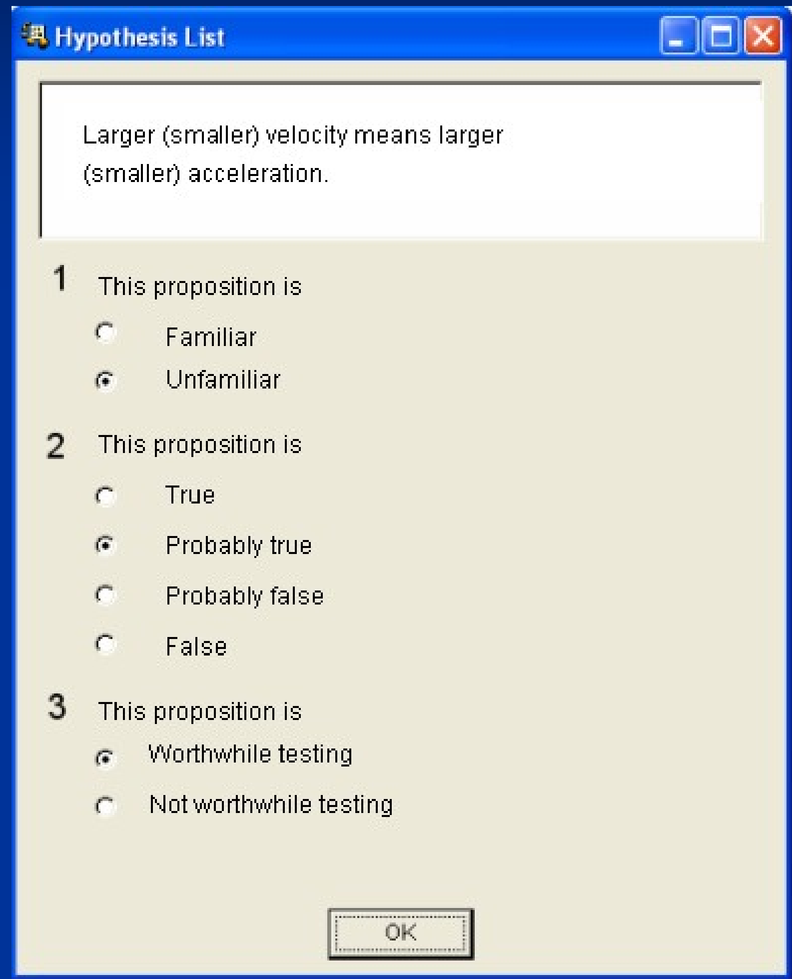
Supporting collaborative discovery

- Domain Kinematics (velocity, acceleration etc.)
- SimQuest simulation
- Three conditions
  - Shared hypothesis scratchpad
  - Shared proposition table
  - Control - Without scaffolds
- 66 students (± 15 years old)

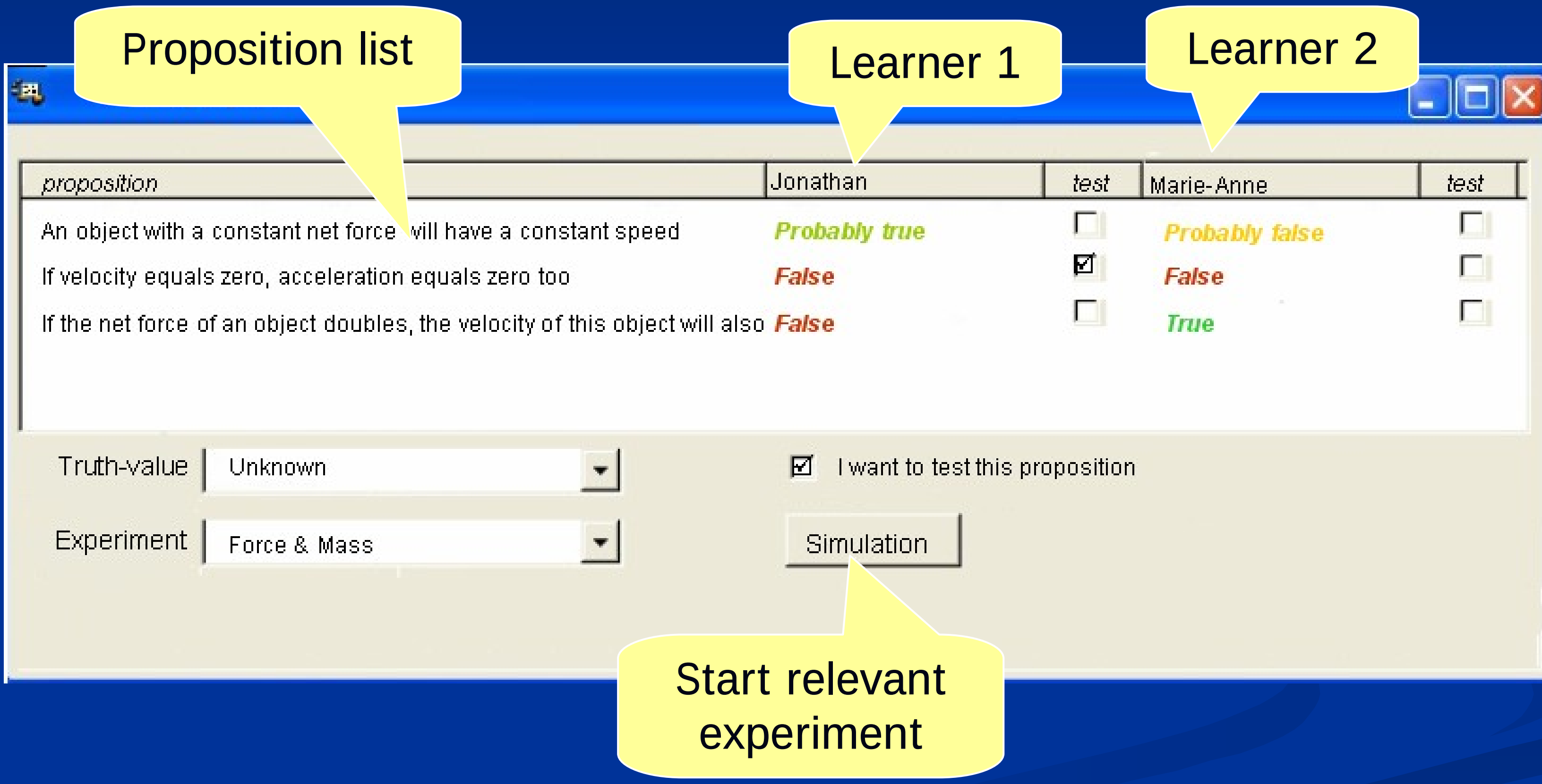
Hypothesis scratchpad



Proposition test



Shared proposition list



Results

- Shared proposition table condition significantly higher learning gains than hypothesis scratchpad
- Shared proposition table condition discussed significantly more unique propositions
- Students working with the shared proposition table explored a larger proportion of the simulated domain

Shared Proposition Table

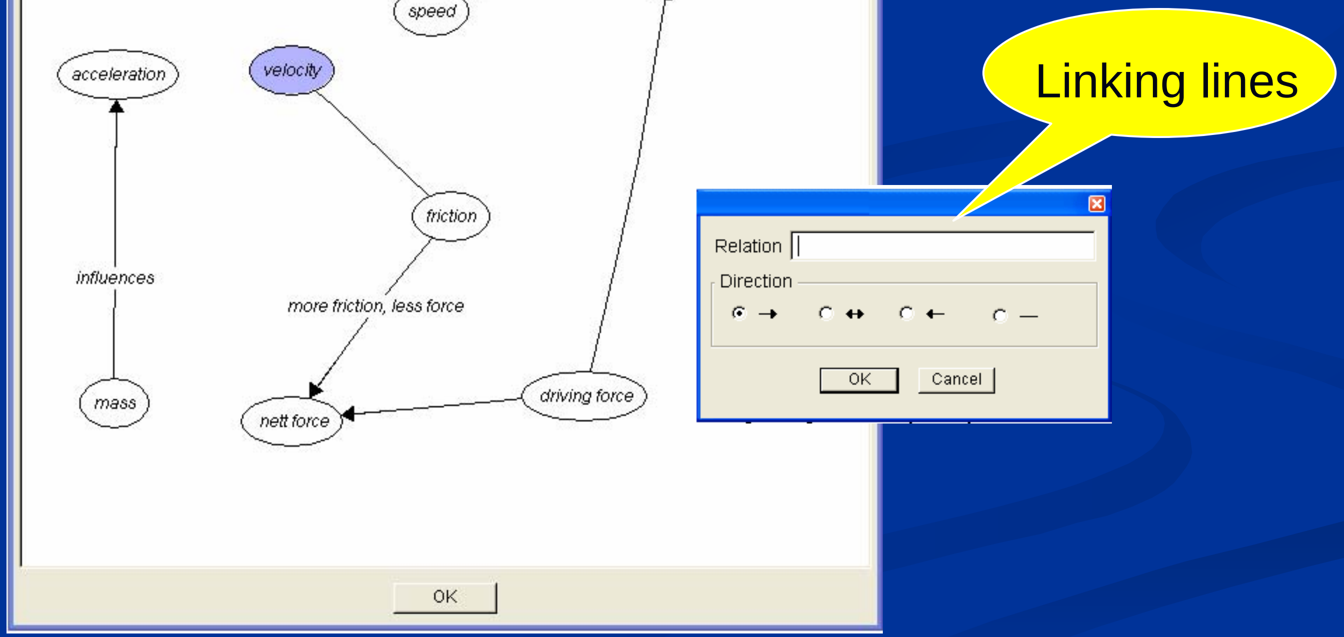
- Pro
  - Helped students maintain a common focus
  - Externalized prior knowledge and ideas
  - Triggered the discussion about propositions
- Con
  - Students tend to focus on cases of disagreement
  - Students treat propositions as isolated statements

Concept mapping tool

- Students create a shared overall representation of the domain

- Requires students to:
  - Identify key concepts
  - Logically structure the concepts
  - Link concepts

Concept mapping tool



Experiment

- Domain Kinematics
- Simquest simulation
- Conditions
  - Proposition table
  - Proposition table + concept mapping tool
- Subjects: 24 (around 15 years old)

Results

- Students in both groups improved on knowledge tests
- Students in the concept mapping condition reached significantly higher learning gains than the proposition table only
- In the proposition table only, more experiments were conducted but in the concept mapping condition there was more discussion per experiment
- Students did not use the concept mapping tool as a support for the simulation, but used the simulation to work on the concept map

When is inquiry learning effective?

- When the right type of domains is used (conceptual instead of operational)
- When relevant cognitive processes are triggered and scaffolded (either by the system or by a co-learner or by both)
- When the appropriate (prior) knowledge is available (either with the (co-)learner or in the system)
- When learners have a goal to work to (e.g., a hypothesis, a model, or a concept map)

Where does intelligence come in?

- We could use more adaptive scaffolding:
  - this means adapting it to the characteristics of students and
  - adapting it over time (fading)
- So, we need some kind of learner model
  - Unpredictable process
    - Pattern identification
  - Unpredictable product
    - Assessing the model that is built by learners

Our 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
  - Interaction data
  - Assessment of models

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