



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

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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

Startscherm

tr@nsferW

versie 1.1

SIMQUEST SIMULATIE
Toestandsdiagrammen

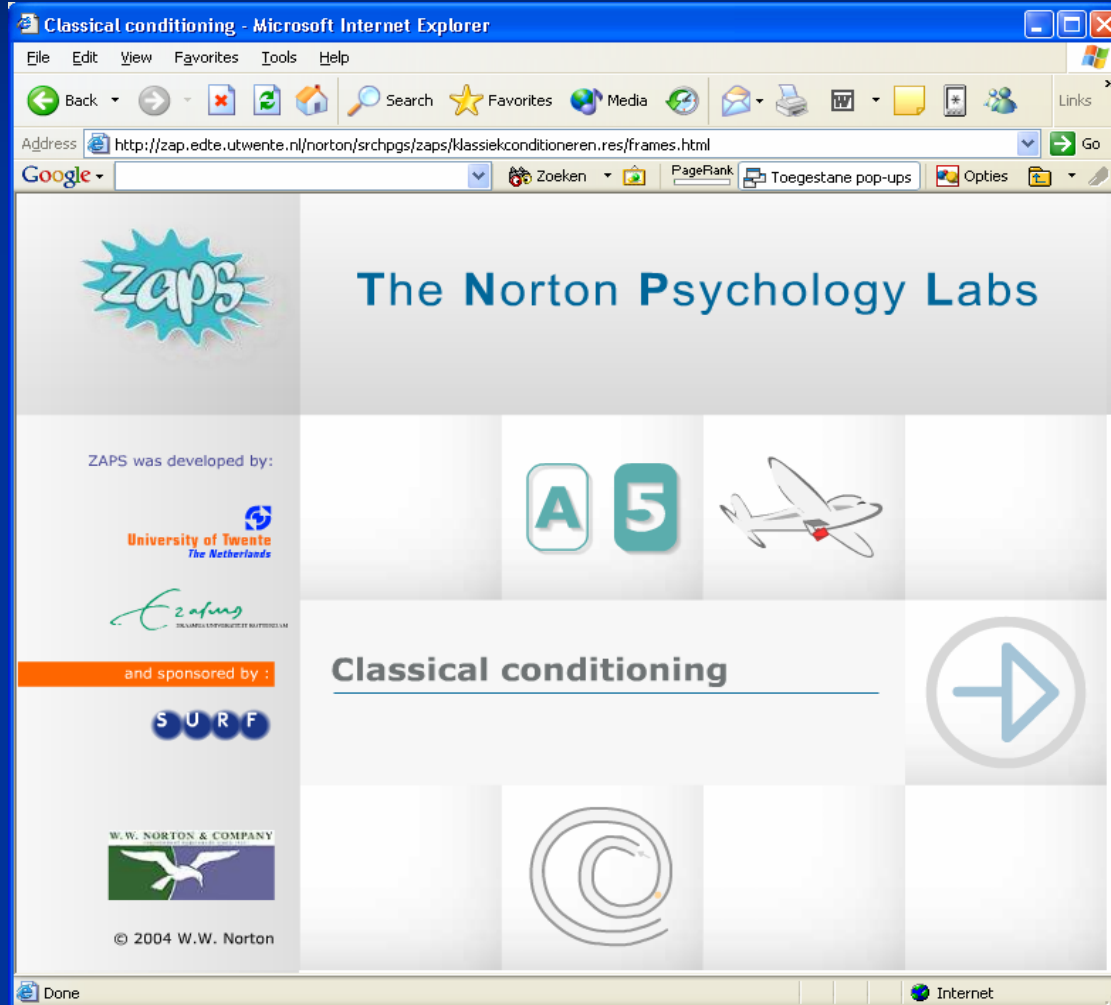
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Start

An example ZAP simulation






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

The screenshot displays the Co-Lab software interface for a 'Tank Level Laboratory' simulation. The interface is divided into several functional areas:

- TOOLS:** Includes Graph, Help, Table, Tank Level Laboratory, and Process Coordinator.
- ROOMS:** Shows a 3D view of the laboratory with buttons for Theory, Lab, Meeting, Hall, Logout, and Change Floor.
- USERS IN GROUP ONLINE:** Lists Leendert, Elwin, and Wouter with status indicators.
- Simulation Controls:** Features a 3D tank model and a control panel with sliders for Tank diameter (0.20-0.25 m), Flow from tap (0-100 L/min, set to 56), and Hole diameter (0.0-0.02 m, set to 0.020).
- Table:** A data table with columns for Level in tank (m) and Out vel... (m/s). It lists various phenomena and their corresponding values.
- Graph:** A line graph showing Level in tank (m) vs. time (s). Two series are plotted: DS1: Level_in_tank (red) and PH4: Level_in_tank (blue). The y-axis ranges from 0.200 to 0.450, and the x-axis ranges from 0 to 300.
- CHATBOX:** A chat window showing a conversation about changing the hole diameter.
- REPOSITORY:** A section for managing simulation scenarios, currently showing 'With small inflow'.

Phenomena	Level in tank (m)	Out vel...
With small inflow	0.2000	1.9809
Flow_from_tap	0.2062	2.0113
Hole_Diameter	0.2122	2.0404
Hole_Section	0.2180	2.0682
Inflow_rate	0.2237	2.0948
Initial_tank_level	0.2291	2.1203
Level_in_tank	0.2345	2.1448
Out_velocity	0.2396	2.1683
Overflow	0.2447	2.1909
	0.2495	2.2127
	0.2543	2.2336
	0.2589	2.2538
	0.2634	2.2732
	0.2678	2.2920
	0.2720	2.3102

Chat log:

- 29.10.2004 13:28:19 (Elwin - Lab) shall we change the diameter?
- 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

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

Moment (dynamic) (1)

$M = 400.0 \text{ kNm}$

$a = 20.0 \text{ m}$

$F = 20 \text{ kN}$

$h = 5 \text{ m}$

3 Elevation level (up/down)

You have 1 attempt left

Question

Does an elevation level (up and/or down) influence the size of the moment?

Answers

- a. yes, but only an upward movement
- b. yes, but only a downward movement
- c. yes, movement upwards as well as downwards
- d. neither has influence on the moment

Answer Close

3 a. not right

This is not right.

Try to find the right answer by changing the elevation level and looking at the size of the moment.

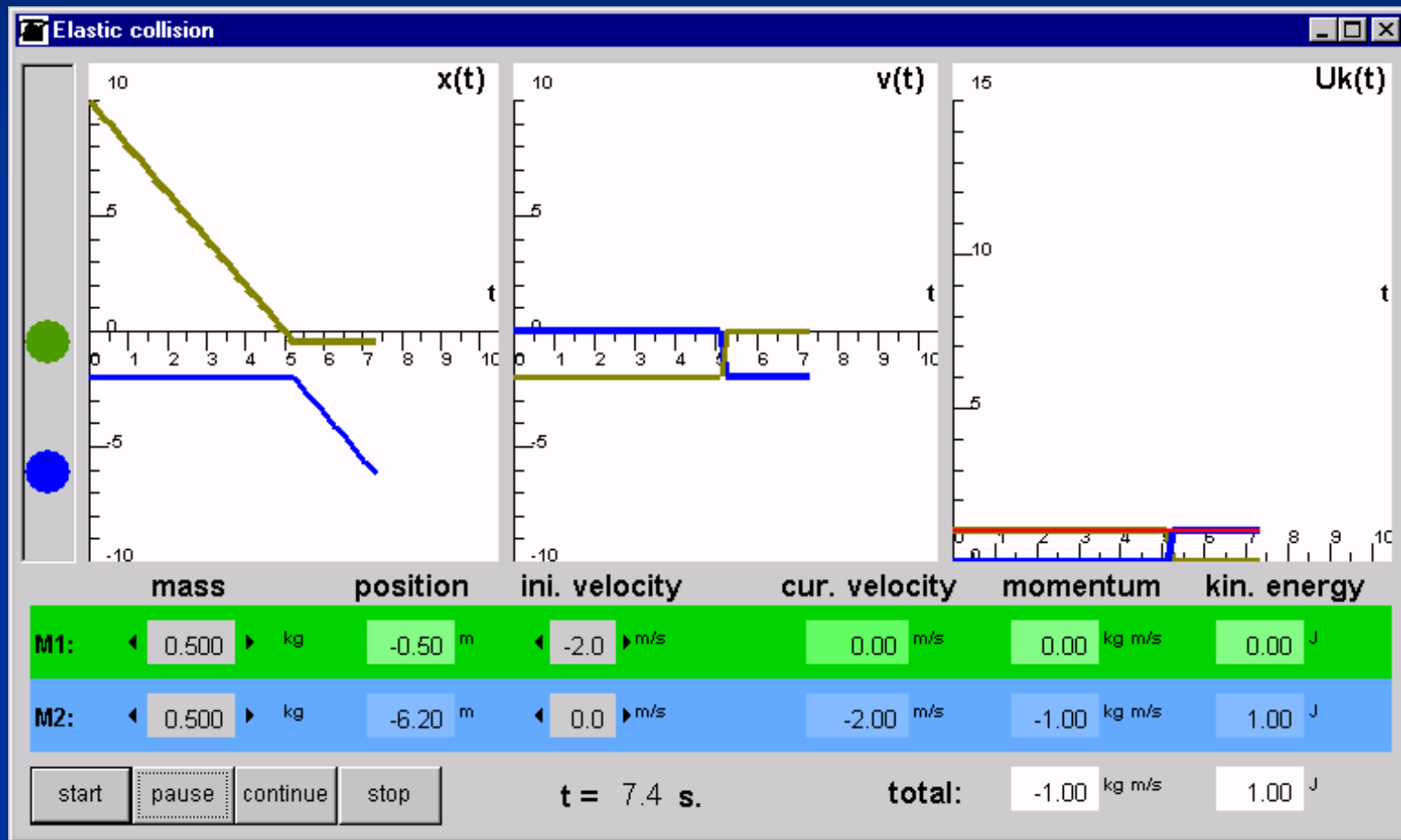
If the movement is too fast, you can use the "Simulation delay".

Close

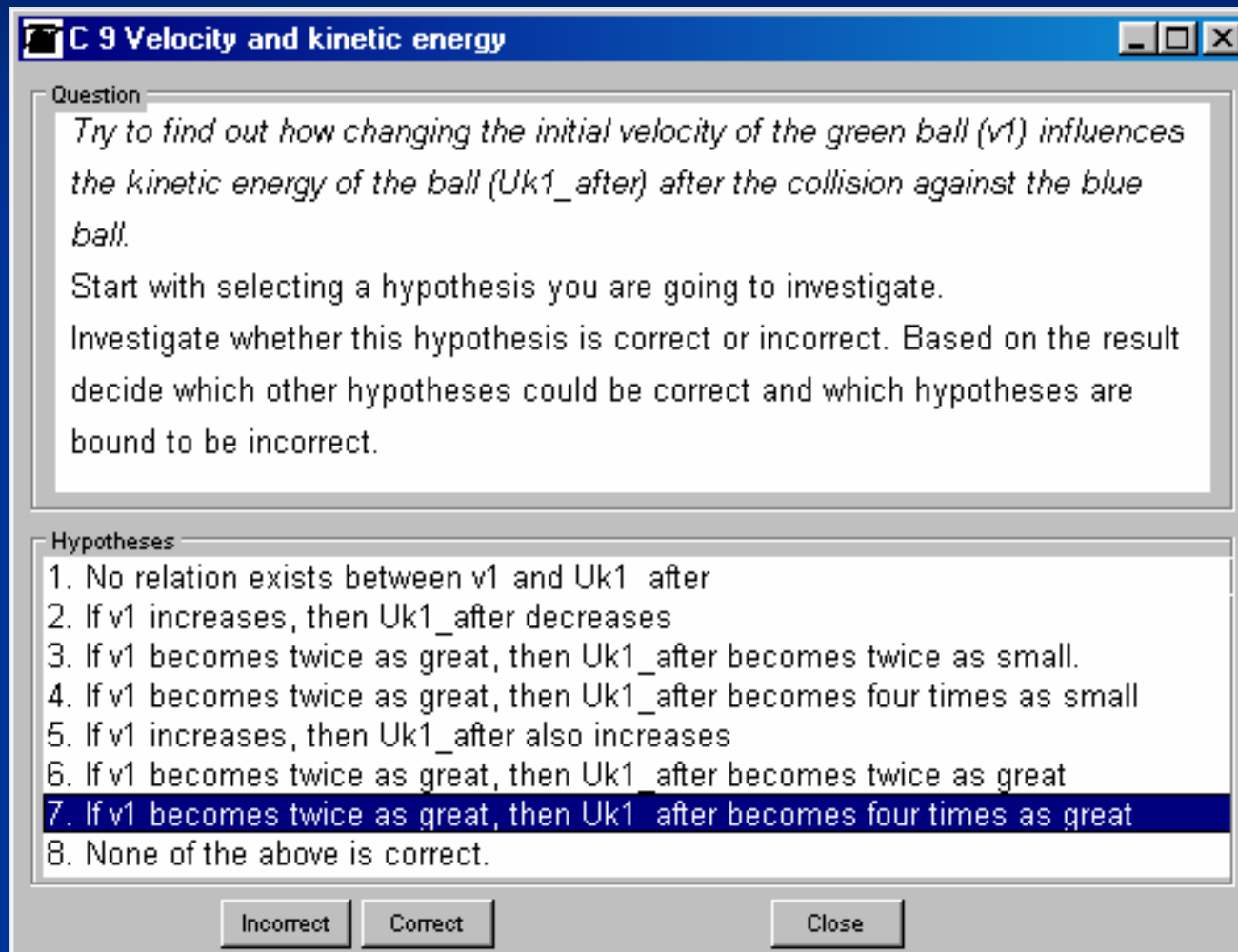
Results of scaffolding

- 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



C 9 Velocity and kinetic energy

Question

Try to find out how changing the initial velocity of the green ball (v_1) influences the kinetic energy of the ball (U_{k1_after}) after the collision against the blue ball.

Start with selecting a hypothesis you are going to investigate.

Investigate whether this hypothesis is correct or incorrect. Based on the result decide which other hypotheses could be correct and which hypotheses are bound to be incorrect.

Hypotheses

1. No relation exists between v_1 and U_{k1_after}
2. If v_1 increases, then U_{k1_after} decreases
3. If v_1 becomes twice as great, then U_{k1_after} becomes twice as small.
4. If v_1 becomes twice as great, then U_{k1_after} becomes four times as small
5. If v_1 increases, then U_{k1_after} also increases
6. If v_1 becomes twice as great, then U_{k1_after} becomes twice as great
7. If v_1 becomes twice as great, then U_{k1_after} becomes four times as great
8. None of the above is correct.

Incorrect Correct Close

Feedback generation

- Student receives an assignment
- Student selects a hypothesis:
 - “a greater mass m_1 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

Feedback on statement and experiments

You claim that the statement 4. *If m_1 becomes 4 times as big than the velocity after the collision becomes twice as big* is true.

Below you will find your experiments that are relevant for testing this statement.

v_1	v_2	m_1	m_2	v_1 after	prediction
-2	0	1	1.0	-0.67	
-2	0	4	1.0	-1.33	-1.33
v_1	v_2	m_1	m_2	v_1 after	prediction
-2	0	0.5	1.0	-0.67	
-2	0	2	1.0	-1.33	-1.33
-2	0	8	1.0	-1.18	-2.67
v_1	v_2	m_1	m_2	v_1 after	prediction
-2	0	1	1.0	-1.6	-2
-2	0	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

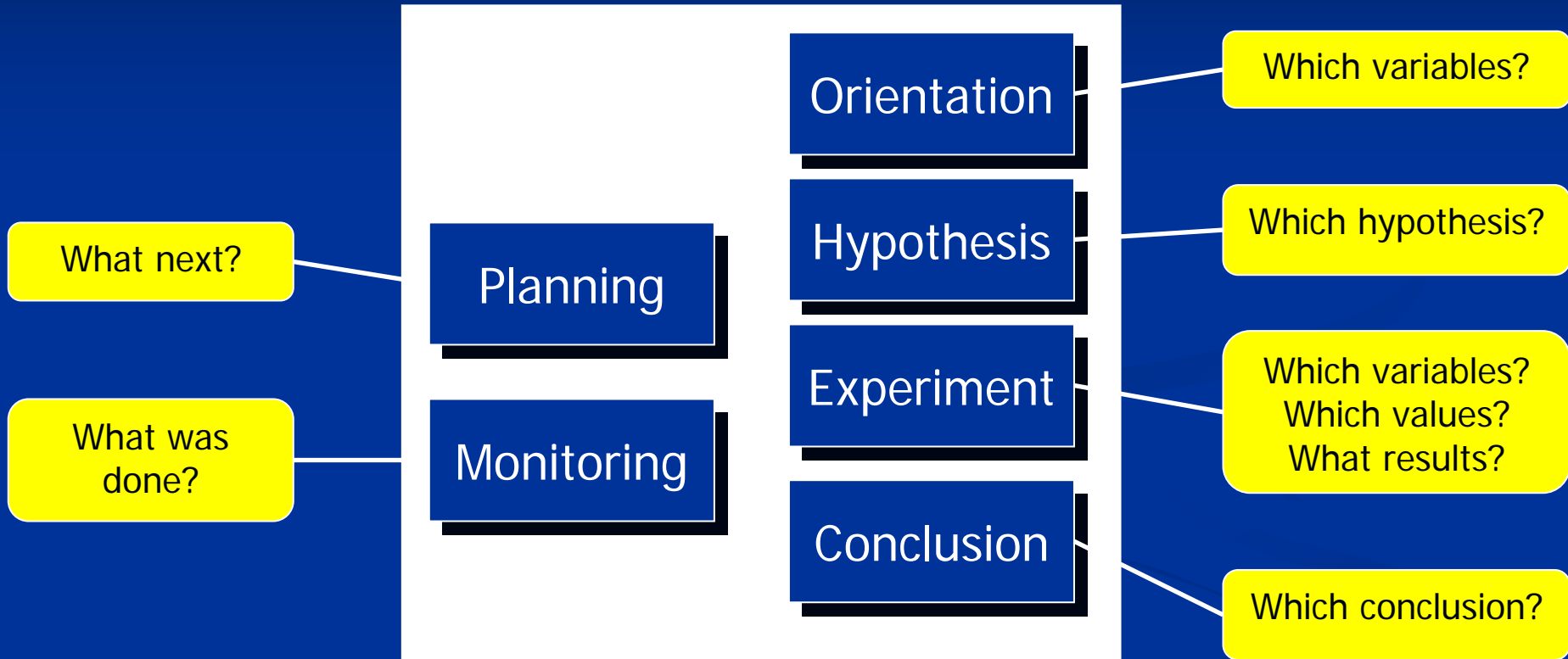
- Knowledge gain
- More assignments

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 (\pm 15 years old)

Hypothesis scratchpad

scratchpad

If

then

if also

If m_total increases, then vt decreases

Proposition Proposition needs testing

<i>proposition</i>	<i>answer</i>	<i>test</i>
If m_total increases, then vt decreases	true	untested
If F_drive decreases fast, then vt decreases	true	tested

Proposition test

Hypothesis List

Larger (smaller) velocity means larger (smaller) acceleration.

1 This proposition is

- Familiar
- Unfamiliar

2 This proposition is

- True
- Probably true
- Probably false
- False

3 This proposition is

- Worthwhile testing
- Not worthwhile testing

OK

Shared proposition list

Proposition list

Learner 1

Learner 2

proposition	Jonathan	test	Marie-Anne	test
An object with a constant net force will have a constant speed	<i>Probably true</i>	<input type="checkbox"/>	<i>Probably false</i>	<input type="checkbox"/>
If velocity equals zero, acceleration equals zero too	<i>False</i>	<input checked="" type="checkbox"/>	<i>False</i>	<input type="checkbox"/>
If the net force of an object doubles, the velocity of this object will also	<i>False</i>	<input type="checkbox"/>	<i>True</i>	<input type="checkbox"/>

Truth-value | Unknown

Experiment | Force & Mass

I want to test this proposition

Simulation

Start relevant experiment

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

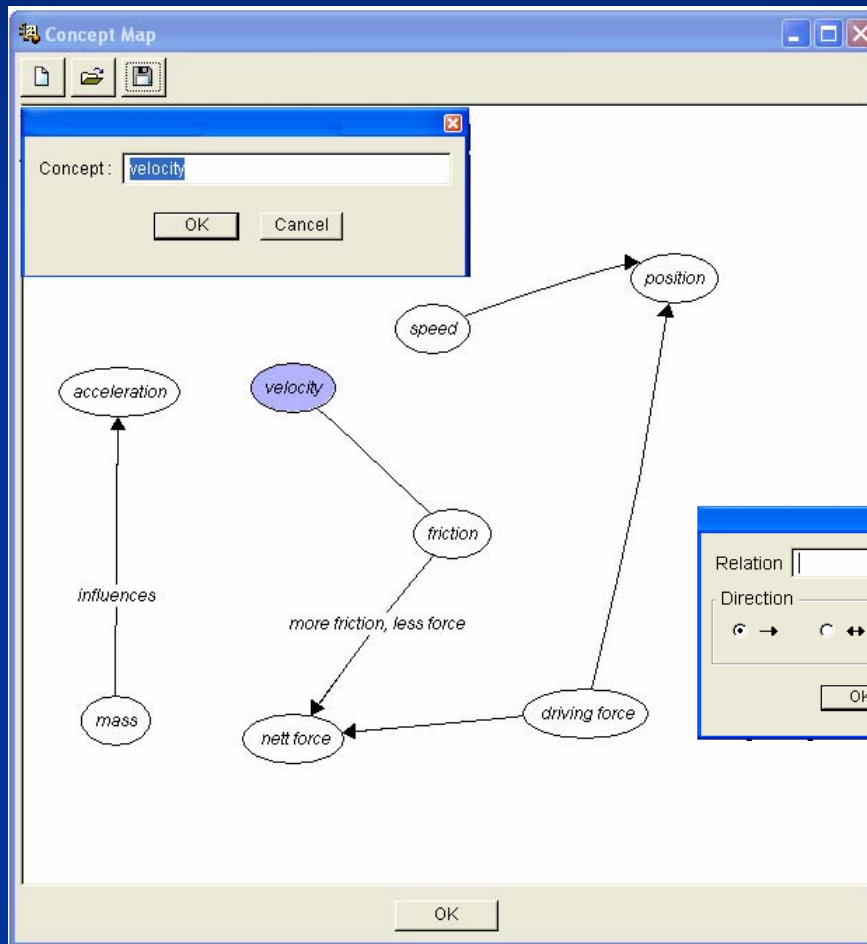
■ Con

- Students tend to focus on cases of disagreement
- Students treat propositions as isolated statements

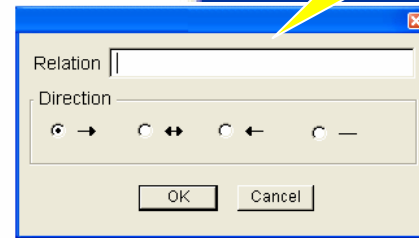
Concept mapping tool

- Students create a shared overall representation of the domain
- Requires students to:
 - Identify key concepts
 - Logically structure the concepts
 - Link concepts

Concept mapping tool



Linking lines



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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