

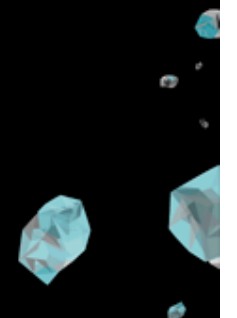
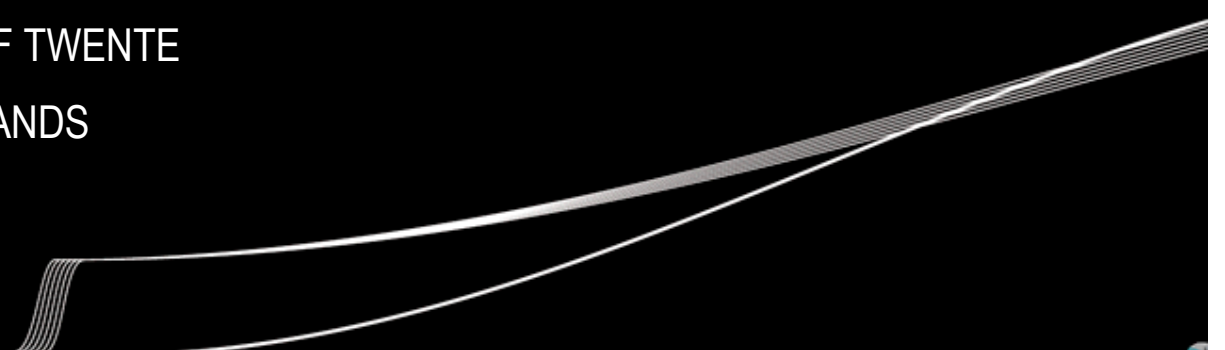
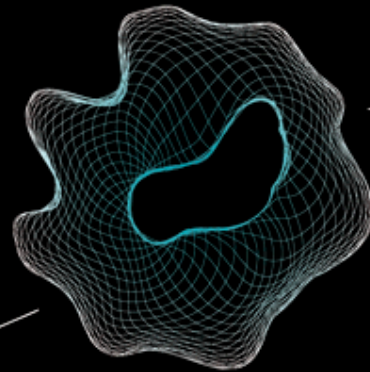
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***FUTURE DEVELOPMENTS IN EDUCATIONAL  
SCIENCE AND TECHNOLOGY ENHANCED LEARNING***

TON DE JONG

UNIVERSITY OF TWENTE

THE NETHERLANDS





## OVERVIEW OF THE PRESENTATION

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- 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 EDUCATION

Constructive learning

Collaborative learning

Individual

Social

Technology  
Enhanced  
Learning

Contextual

Situated learning



# DEVELOPMENTS IN TECHNOLOGY ENHANCED LEARNING

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- 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

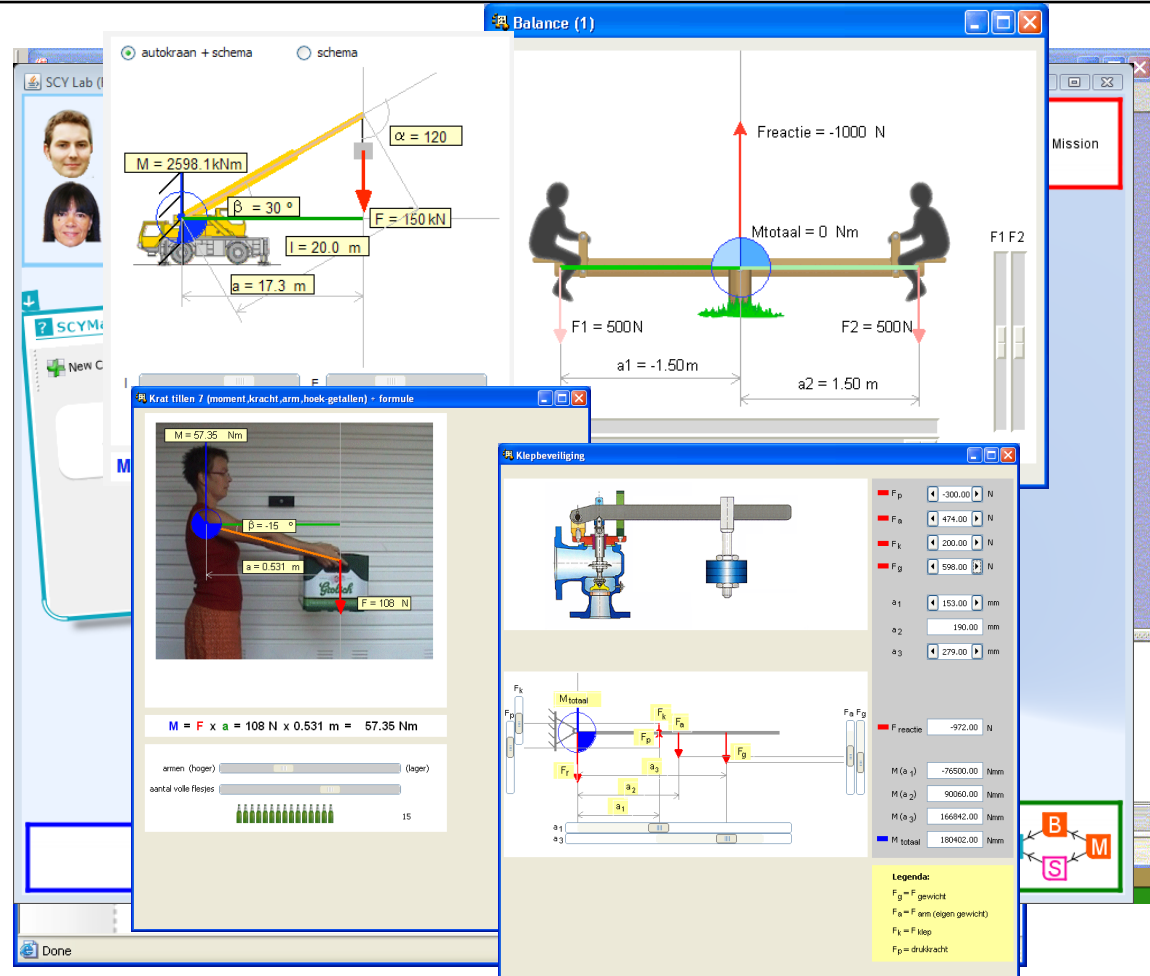
■ SimQuest

■ Co-Lab

■ KMQuest

■ ZAP

■ SCY



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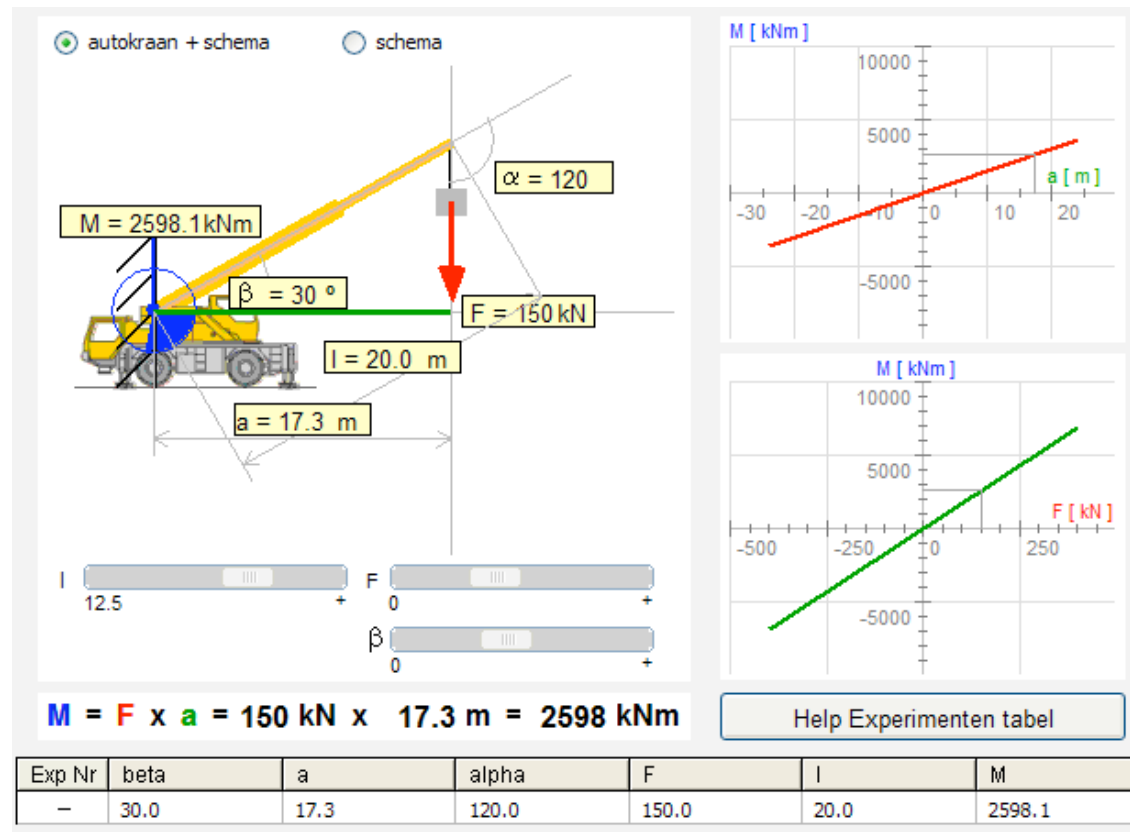


## WHY SHOULD LEARNING WITH SIMULATIONS WORK?

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- 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





## BUT IT DOESN'T WORK JUST LIKE THAT!

SCAFFOLDING IS NEEDED

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- Orientation
- Hypothesis generation
- Experimentation
- Concluding
- Planning
- Monitoring
- Reflection
- Connecting representations
- Translating between representations
- Support to contrast cases



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# SIMULATION BASED LEARNING COMPARED TO TRADITIONAL, EXPOSITORY, INSTRUCTION

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- 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*
  - Linn, Lee, Tinker, Husic, & Chiu, 2006: *TELS*
  - de Jong, Hendrikse, & van der Meij, in press: *SimQuest Math*
- Effects on conceptual (intuitive) knowledge



# SIMULATION BASED LEARNING COMPARED TO TRADITIONAL, LABORATORY, INSTRUCTION

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- 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

**11. Runners**

**Settings:**

Total number of runners:

Number of runners in your prediction:

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

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

Eysink, T.H.S., de Jong, T., Berthold, K., Kolloffel, B., Opfermann, M., & Wouters, P. (in press). Learner performance in multimedia learning arrangements: an analysis across instructional approaches. *American Educational Research Journal*



# HOW TO DESIGN SUPPORTIVE INQUIRY ENVIRONMENTS?

## PROBLEMS IN INQUIRY LEARNING

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





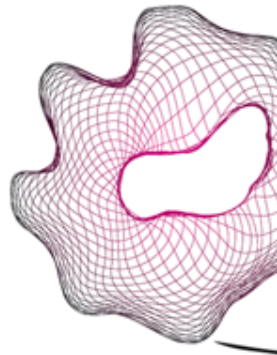
## SCAFFOLDS

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

de Jong, T. (2006). Computer simulations -  
Technological advances in inquiry learning.  
*Science*, 312, 532-533.

# SCAFFOLDS AND COLLABORATIVE INQUIRY



What next?

What was  
done?

Planning

Monitoring

Orientation

Hypothesis

Experiment

Conclusion

Which variables?

Which hypothesis?

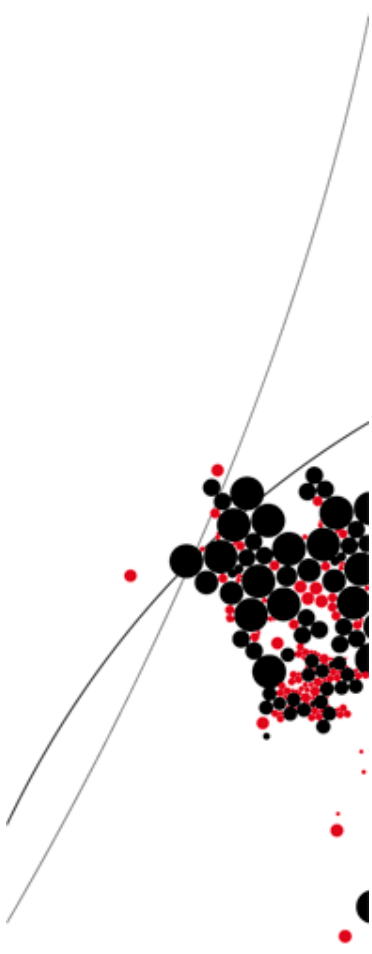
Which variables?  
Which values?  
What results?

Which conclusion?



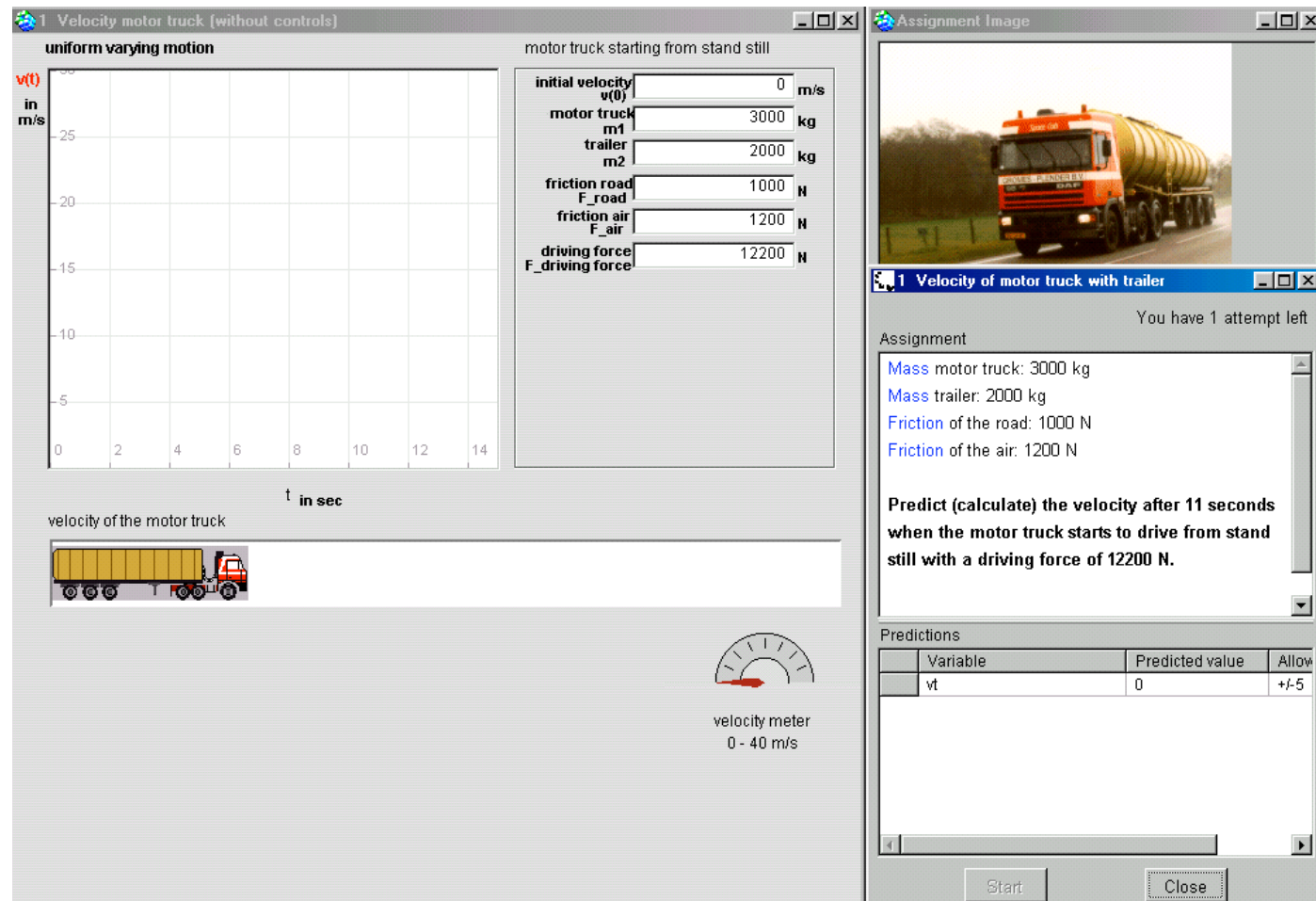
# COLLABORATIVE INQUIRY

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- Differences in opinion should lead to discussion and progress in learning
    - Okada and Simon (1997)
    - Gijlers, H., & de Jong, T. (2005). The relation between prior knowledge and students' collaborative discovery learning processes. *Journal of Research in Science Teaching*, 42, 264-282.
  - Focus on hypothesis generation
    - Gijlers, H., & de Jong, T. (2009). Sharing and confronting propositions in collaborative inquiry learning. *Cognition and Instruction*, 27, 239-268.
- 



# SUPPORTING COLLABORATIVE INQUIRY



1 Velocity motor truck (without controls)

uniform varying motion

motor truck starting from stand still

initial velocity $v(0)$	0	m/s
motor truck $m_1$	3000	kg
trailer $m_2$	2000	kg
friction road $F_{road}$	1000	N
friction air $F_{air}$	1200	N
driving force $F_{driving force}$	12200	N

velocity of the motor truck

velocity meter  
0 - 40 m/s

Assignment Image

1 Velocity of motor truck with trailer

You have 1 attempt left

Assignment

Mass motor truck: 3000 kg  
Mass trailer: 2000 kg  
Friction of the road: 1000 N  
Friction of the air: 1200 N

Predict (calculate) the velocity after 11 seconds when the motor truck starts to drive from stand still with a driving force of 12200 N.

Variable	Predicted value	Allow
$v_t$	0	$\pm 5$

Start Close

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# SHARED PROPOSITION LIST

Proposition list

Learner 1

Learner 2

Shared proposition table				
proposition	Jonathan	test	Marie-Anne	test
An object with a constant net force will have a constant speed	Probably true	<input type="checkbox"/>	Probably false	<input type="checkbox"/>
If velocity equals zero, acceleration equals zero too	False	<input checked="" type="checkbox"/>	False	<input type="checkbox"/>
If the net force of an object doubles, the velocity of this object will also	False	<input type="checkbox"/>	True	<input type="checkbox"/>
Truth-value	Unknown	<input checked="" type="checkbox"/> I want to test this proposition		
Experiment	Force & Mass	Simulation		

Start relevant experiment

# PROPOSITION SCRATCHPAD

**scratchpad**

If

then

☐ if also

If m\_total increases, then vt decreases

Proposition  ☐ Proposition needs testing

proposition	answer	test
If m_total increases, then vt decreases	true	untested
If F_drive decreases fast, then vt decreases	true	tested



## RESULTS (IN A NUTSHELL)

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- 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,

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- Basic research
  - Experimental studies (smaller ( $n = \text{approx } 25$  per condition) or larger number ( $n = 100+$  per condition) of students)
  - Small scale, qualitative, studies
  - In realistic situations
- Usability studies
  - (Larger scale) applications



## TECHNIQUES USED

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- Experimental manipulations: pre-test post-test control group design
- Knowledge tests, questionnaires
- Process analysis
  - Thinking aloud protocols
  - Log-file analysis
  - Chat analysis
  - Neuropsychological techniques





## EXAMPLE OF A STUDY WITH NEURO-TECHNIQUES

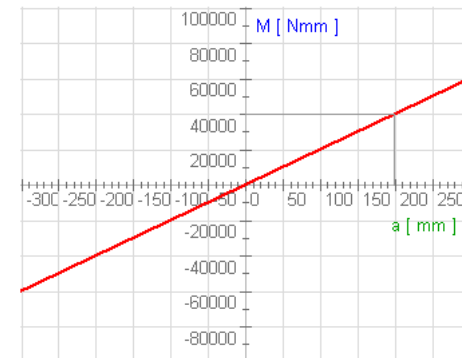
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- Question: How do students process different representations?
- 18 subjects, within subject design
- Four representations: Concrete, Formula, Table, Graph
- No task and task conditions (identify values)
- EEG: Event related potentials
- Van Leeuwen, Th., van der Meij, J. & de Jong, T. (submitted). Event-related potentials as a window on external representations

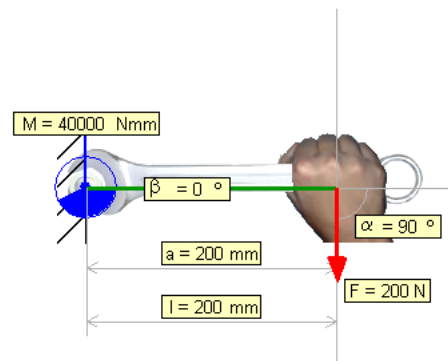


# REPRESENTATIONS USED

$$M = F \times a = 200 \text{ N} \times 200 \text{ mm} = 40000 \text{ Nmm}$$



F	alpha	beta	l	a	M
-350	90	0	200	200	-70000
-300	90	0	200	200	-60000
-250	90	0	200	200	-50000
-200	90	0	200	200	-40000
-150	90	0	200	200	-30000
-100	90	0	200	200	-20000
-50	90	0	200	200	-10000
0	90	0	200	200	0
50	90	0	200	200	10000
100	90	0	200	200	20000
150	90	0	200	200	30000
200	90	0	200	200	40000
250	90	0	200	200	50000
300	90	0	200	200	60000
350	90	0	200	200	70000







# RESULTS

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- 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

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- *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

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- 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



## CONCLUSIONS

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