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Design principles
for digital modules for Advanced Mathematics
that cater for both
procedural fluency and conceptual understanding

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Introduction

- Transition secondary schools – higher education
- Attractiveness science and maths
- Curriculum: new content for mathematics D - small classes, teacher shortage
- Instruction in Virtual Learning Systems (VLS): platforms for delivering learning content, engaging learners, and measuring their performance
- Design of VLS modules for maths

VLS modules

- replacement of paper module (text book), and partially the teacher as well
- *blended-learning* (f2f is not excluded)
- teacher manages the VLS
- Not:
  - online live teaching (web-class, webinar)
  - assessment only
  - algebraïc proficiencies
  - practice-and-drill

VLS modules

- Content (audio, written texts, diagrams, movies, ..)
- Communication (synchronous, asynchronous)
- Tasks (closed, open, adaptive, immediate feedback, ..)
- Math software (Geogebra, DWO, spreadsheets, applets, etc.)

(Kerres & De Witt, 2003; Lai, 2008)

Designing VLS modules

Graph Theory
Discrete Dynamical Systems
Cryptography
Logic
Coordinate Geometry
Probability
Poincaré
Differential Equations

Design teams: 1-3 authors per module

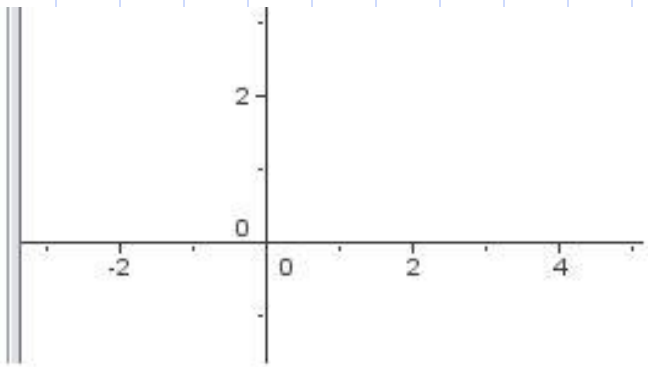
Designers: experienced teachers, but also student-teachers, textbook authors, e-learning designers, one teacher trainer

Intervision meetings

tonen, etc. Experimenteer zelf...

Hieronder kun je zien hoe het schatgraversprobleem is geconstrueerd, een mooie oefening.

Bron: Math4all



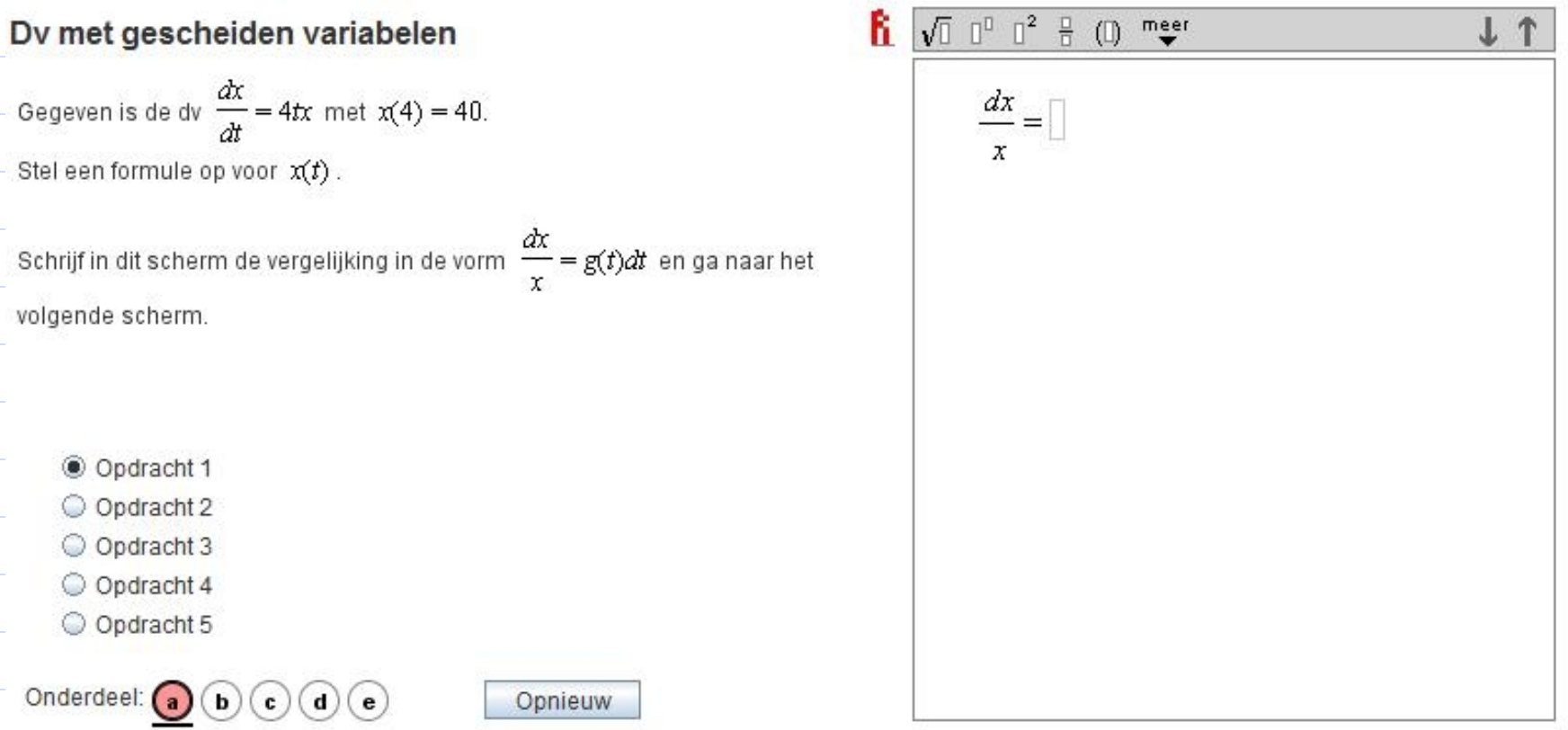
GeoGebra Practicum

Het schatgraverprobleem meetkundig...
E is variabel, Z_1 en Z_2 liggen vast.
Gegeven: $|EZ_1| = |Z_1P|$ en $|PZ_2| = |Z_2Q|$ en de hoeken EZ_1P en PZ_2Q zijn recht.
Gevraagd is aan te tonen dat het midden S van EQ niet van plaats kan veranderen.

De constructie gaat zo:

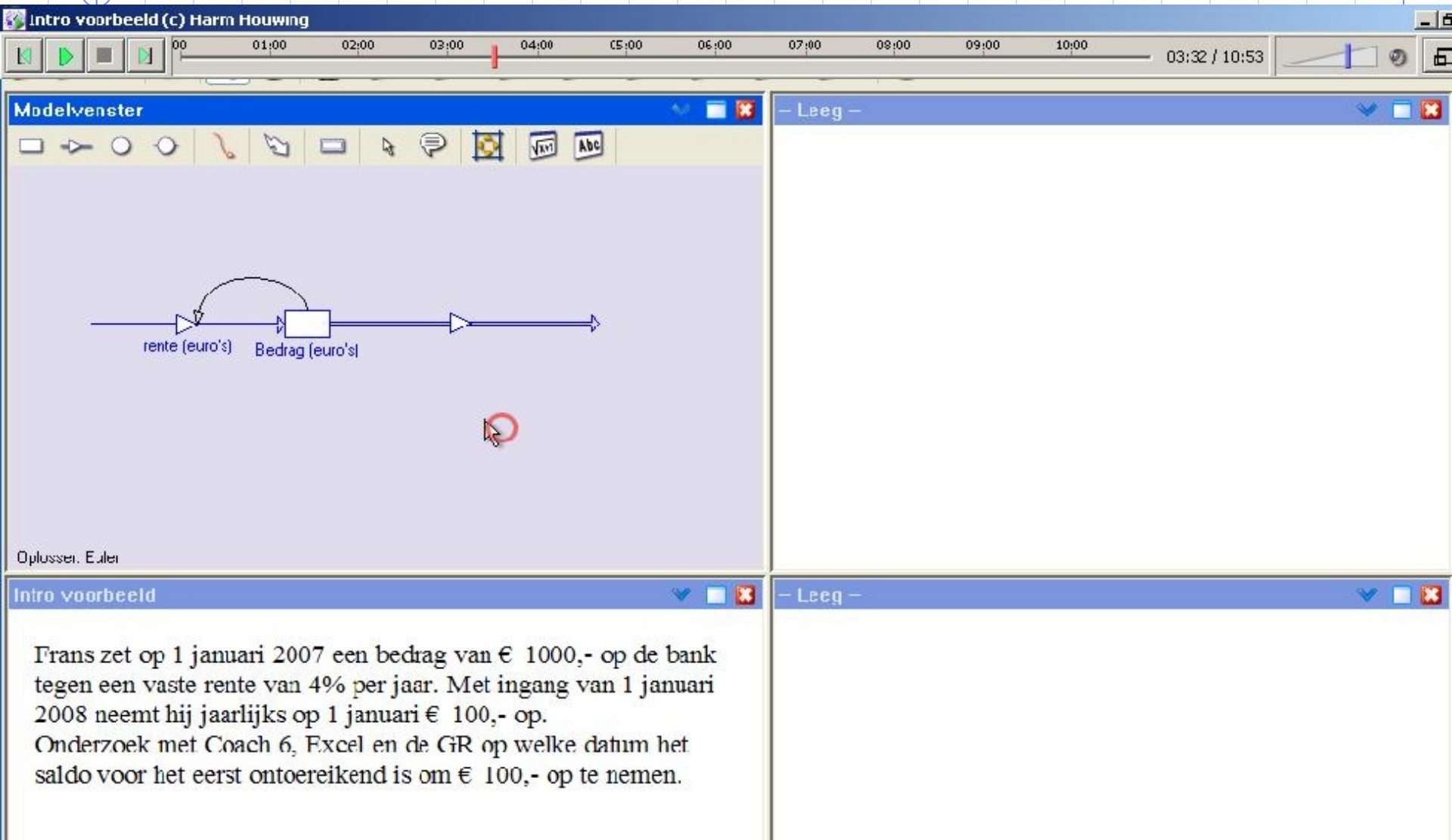
1. Plaats drie punten (niet op één lijn) en noem ze E (oude eik), Z_1 en Z_2 (de zwerfkeien).
2. Maak lijnstuk EZ_1.
3. Maak lijn b door Z_1 en loodrecht EZ_1.
4. Maak cirkel c met middelpunt Z_1 en door E.
5. Maak punt P, het snijpunt van cirkel c en lijn b.
6. Maak lijnstuk PZ_2.
7. Maak lijn e door Z_2 en loodrecht PZ_2.
8. Maak cirkel f met middelpunt Z_2 en door P.
9. Maak punt Q, het snijpunt van cirkel f en lijn e.
10. Maak lijnstuk QE.
11. Maak punt S het midden van QE.

Procedural scaffolding



Frequently used: *screencast*

example



screencast

- Actions on the screen with verbal explanation
- Udell (2004, 2005): *“a digital movie in which the setting is partly or wholly a computer screen and in which audio narration describes or explains the story on the on-screen action.”*
- talk and show simultaneously
- accessible vocabulary
- often: demonstration of worked-out examples

Focus on procedures strong in *chat* sessions (Oosterling, 2008)

niels (13-jun-2008 15:12 CEST) hallo

maxim (13-jun-2008 15:16 CEST) in the video they say that you must use the ebsilon, and increase the path with it... We did it differently, we did not increase it each time with the maximal in the path. But it is correct through out. Do you know whether this is correct, or is ours also allowed?

niels (13-jun-2008 15:22 CEST) maxim, you should use the described algorithm

pim (13-jun-2008 15:35 CEST) does not matter

pim (13-jun-2008 15:35 CEST) who has already finished

maxim (13-jun-2008 15:41 CEST) bye

Prior study: evaluation of the first six prototype modules (Vos, 2010)

Strong focus on procedures:

- Demonstrations through **worked-out examples** 'how to do a certain task'
- Lists with **step-by-step** actions (algorithms)
- How-to course *Learning-to-use-ICT* followed by *Using ICT to apply to this particular type of exercise*
- Little focus on developing conceptual knowledge.

One module is exceptional: contains relatively many 'deep thoughts' tasks – Cryptography.
For example using 'what if..' questions on content.

Math proficiency

- Procedural fluency – the “how”
- Conceptual understanding – integrated and functional grasp of mathematical ideas

  (Hiebert & Carpenter, 1992; Kilpatrick, Swafford & Findell, 2001; Skemp, 1976)

- There is a plethora of research:
  - Proc fluency does not generate conc understanding
  - Proc fluency is easily forgotten (short term retention)

  (Anderson, 1993; Baroody & Gannon, 1984; Briars & Siegler, 1984; Greeno, Riley & Gelman, 1984; Hiebert & Wearne, 1996; Rittle-Johnson, Siegler & Alibali, 2001)

Figure 1.5 Three Kinds of Multimedia Learning Outcomes

		Test performance	
Learning outcome	*Cognitive description*	*Retention*	*Transfer*
No learning	No knowledge	Poor	Poor
Rote learning	Fragmented knowledge	Good	Poor
Meaningful learning	Integrated knowledge	Good	Good

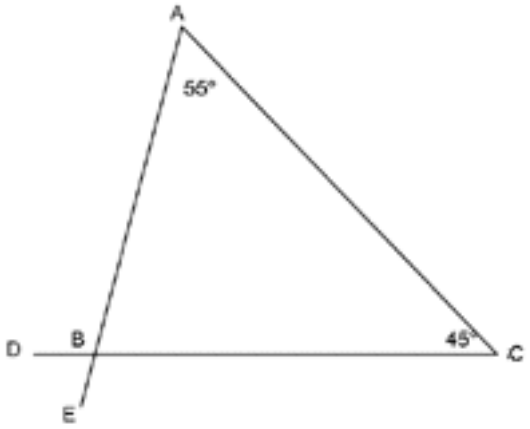
(Mayer, 2001, p. 17)

Design principles for e-learning (Mayer, 2001, 2005; Clark & Mayer, 2003)

For designing in VLS environments:

- Multimedia principle: multiple representations
- Modality principle: replace written text by spoken text animations
- Spatial and t information s
- Redundancy
- Coherence p
- Personalisati
- Segmenting

Example demonstrating split attention



In the above figure, find a value for Angle DBE

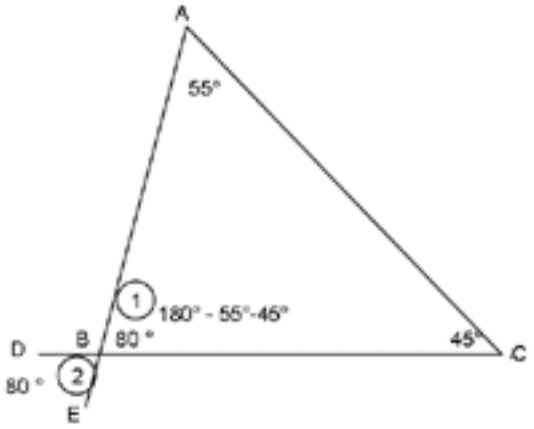
Solution:
Angle ABC =180° - Angle BAC-Angle BCA (internal angles of a triangle sum to 180°)

= 180° - 55°-45°

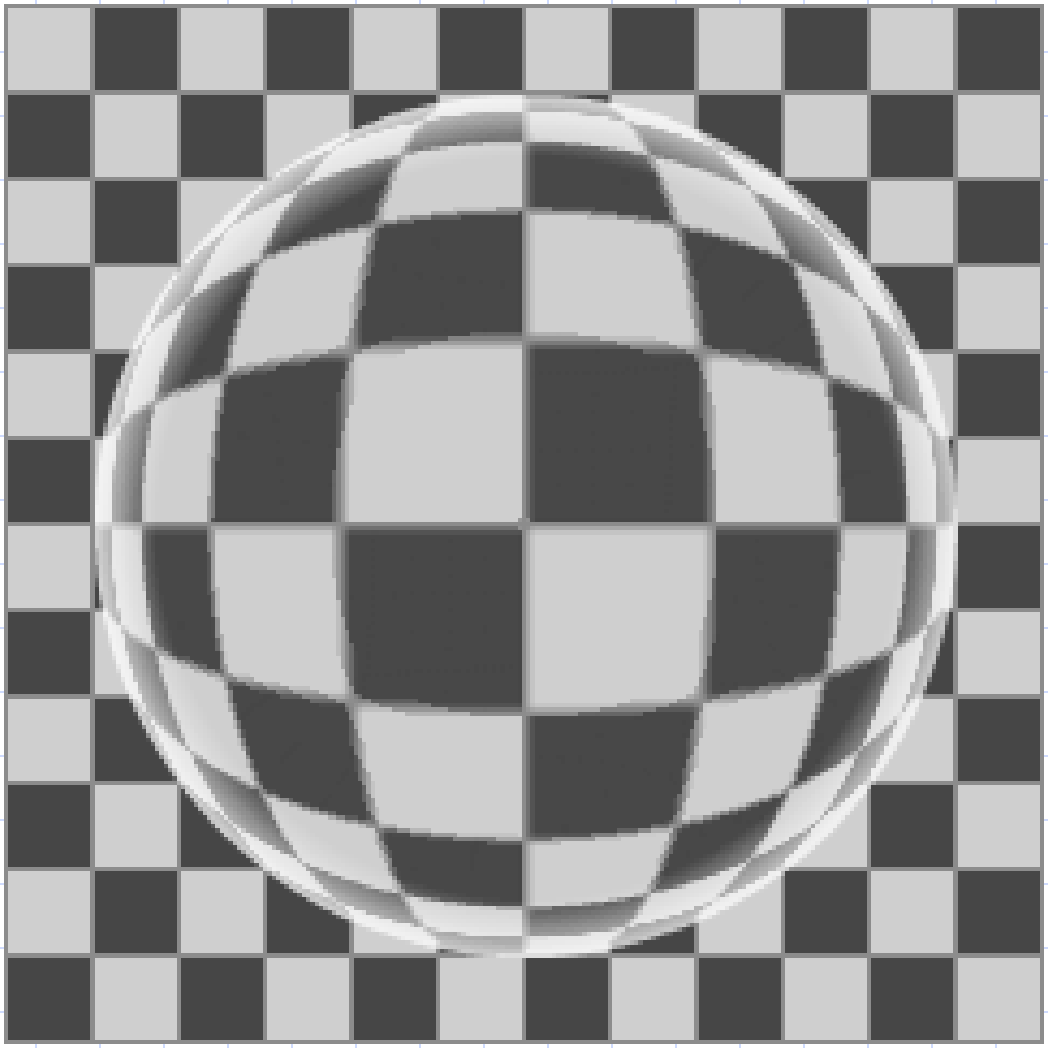
= 80 °

Angle DBE = Angle ABC (vertically opposite angels are equal)
= 80 °

Integrated example



VLS modules as a lense on design of math instruction



- To what extent do Mayer's principles assist to (re-)design a VLS module Logic aiming at a mix of conceptual and procedural learning?

Results

Design principle	Examples of implementation
Multimedia	Link to Youtube, figures, applets, cartoons
Modality	spoken text, screen cast
Spatial & temporal contiguity	exercise blocks, immediate feedback
Redundancy	(hopefully)
Coherence	Tasks on the same page as explanation
Personalisation	Page: “Is this module something for you?” Our names & voices
Segmenting	short chunks

Results

Design principles
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- Mayer's design principles are good guidelines for usability, but not for avoiding a focus on procedural knowledge
- Thought provokers (cognitive conflict) can be designed, but we assumed the presence of a teacher in the background
- Need for explicit design principles aiming at conceptual understanding
- Need for more research on VLS and conceptual learning

Discussion

- The medium has potentials:
  - Immediate feedback
  - Variety in representations
  - Integration of software tools
  - Non-linear sequencing of learning activities

- The medium seduces designers to focus on procedural knowledge:
  - VLS have a history in assessment and administration (questions with short answers & only one answer is correct, VLS generates marks)
  - New medium, designers rely on traditions (comfort zone)
  - Use of mathematical *software tools* requires 'learning to use'
  - Anticipated absence of teacher – designer avoids *cognitive conflict*
  - Mathematical symbols, diagrams and language are less suitable for interactive communication (mail, chat, etc)

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