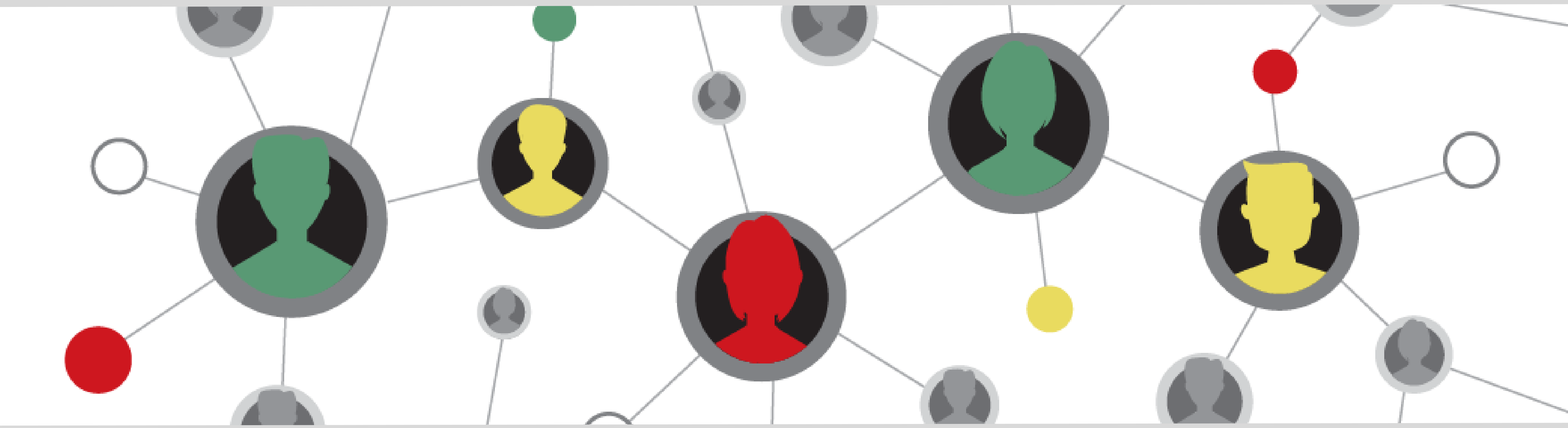
Can computational thinking help students to learn reasoning in physics?

Cathy Baars



Start at 16:45 uur

Content

- What happened?
- What did we do?
- What had to change?
- Our wishes
- How can computational thinking help?

What happened?

- Normally my classes scored better on the central exams than average
- The last two exams they scored lower than average
- There was no change in exam content

1.1 Het centraal examen natuurkunde

De zitting en de zittingsduur van het centraal examen worden gepubliceerd op www.examenblad.nl. Ook wordt daar dan een lijst gepubliceerd met hulpmiddelen die bij het examen zijn toegestaan.

Bij het maken van het centraal examen wordt ernaar gestreefd dat 50% van het totaal aantal scorepunten dat door de kandidaat behaald kan worden, afkomstig is van vragen waarbij voor de beantwoording een expliciete berekening noodzakelijk is.

In bijlage 4 van deze syllabus wordt informatie gegeven over de correctie van het centraal examen natuurkunde.

- In the past 80 – 90 % of the scores were obtained with “calculation” questions
- Now 50 % of the scores must be obtained by “reasoning” questions
- From 25 – 28 questions ≈ 13 – 20 questions are reasoning questions
- We missed 1 sentence in a 41 pages large exam description

...g…

- Scientific l…
- Critical thinking
- Not new but…

- Yellow = scientific literacy related
- Orange = modelling
- Green = calculations

The candidate is able to:

- analyse
- explain
- evaluate
- test
- describe
- perform calculations

…the subjects:

- …nical design
- …
- …
- envi… …l society

in the conte…

- mechanics
- electromagnetis…
- materials
- radiaton
- waves
- quantum dynamics

It is not enough to write some essays

…college,
… plek!

What did we do?

Martinuscollege, jouw plek!

- Systematic Problem Analysis (SPA)
- Helpful for the less brilliant students

What is the question?	
Kind of question (calculation, determination, explain)	
Data and sketch	
Relevant knowledge/formulas	
Plan	
Execution	
The answer: (ALRUS) • answer to the question asked? • logic • readable • units • significance	

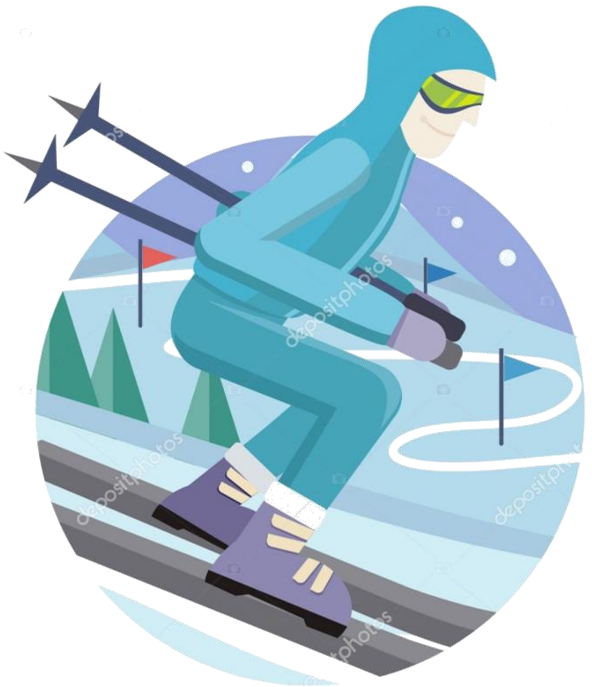
What	How	Known	Needed	Calculation

Very nice way to get insight in the (wrong) steps a student makes to solve a problem

Example of SPA

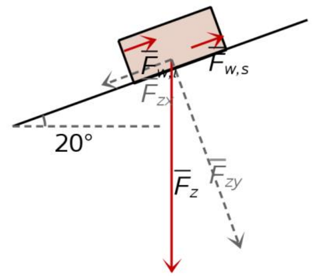
- Skier (m=80 kg) on a slope (20°)
- There is air friction and kinetic friction.
- The air friction constant is 2,0 kg/m
- The kinetic friction coefficient is 0,05
- Initial velocity is 0 m/s

- What is the final velocity?



Example

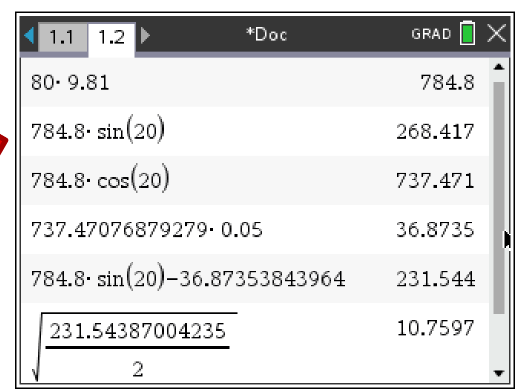
What is the question?	Ve
Kind of question	Calculation
Data and sketch	m= 80 kg α = 20° k1 = 2,0 kg/m k2 = 0,05
Relevant knowledge/formulas	F = m.g Fz//=Fz*sin(α) Fz⊥ = Fz*cos(α) Σ F = 0=F_{wl}+F_{ws}-$F_{z//}$=0 Fwl=k_1*v^2 Fws = k_2*Fn
Plan	
Execution	
The answer: (ALRUS) • Answer to the question asked? • logic • readable • unity • Significance	11 m/s (= 39 km/h)



- Skier (m=80 kg) on a slope (20°)
- There is air friction and kinetic friction.
- The air friction constant is 2,0 kg/m
- The kinetic friction coefficient is 0,05 and is proportional to the normal force
- Initial velocity is 0 m/s

- What is the final velocity?

What	How	Known	Needed	
v	F_{wl} = k_1*v^2	k1	Fwl	11
Fwl	F_{wl}+F_{ws}=$F_{z//}$	-	$F_{z//}$ and F_{ws}	232
Fws	Fws=k_2*Fn=k_2*$F_{z⊥}$	k2	$F_{z⊥}$	37
Fz⊥	$F_{z⊥}$ = F_z*cos(α)	α	Fz	737
Fz	F_z=m.g	m, g	--	785
Fz//	$F_{z//}$=F_z*sin(α)	α	F_z	268
Fz	F_z=m.g	m, g	--	785



Follow up questions

Martinuscollege, jouw plek!

- Calculate the angle of the slope if the final velocity is 15 m/s
- You waxed your skies, now the friction coefficient is 0,01. What is the final velocity?
- You bent more forward so the air friction constant becomes 1,5 kg/m. What is the increase in final velocity?

→ Due to memory overload no deeper learning

Better questions to prepare for scientific literacy

- If you wax your skies, what will happen with the final velocity ? Explain !
- If the slope becomes steeper, what will happen with final velocity ? Explain!
- How will the velocity, time graph change if the air friction is higher? Explain!

→ start a discussion → oral discussion ≠ written scientific literacy

Our wishes

Martinuscollege, jouw plek!

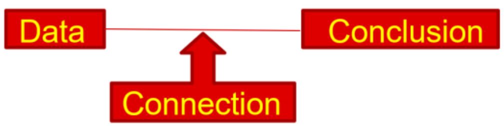
- Using a algorithmic way as strategy for scientific reasoning
- Reduce of working load/memory load to obtain space for understanding

- SPA+
- Algorithmic thinking
- Coding (?)

Computational Thinking and ~~coding~~

Modelling

SPA +

What is the question?	
Type of question (data, connection or conclusion)	
Information, data and sketch	
Relevant knowledge/formulas	
	
Combining all elements	
Is the answer an answer to the question asked?	

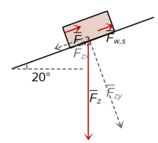
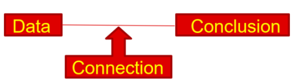
Important to be aware of the different types of questions.

- Data:
  - If the skier wants to go slower at the end, what can he do to obtain that?
- Connection:
  - Explain why the acceleration of the skier becomes zero
- Conclusion:
  - There is frontal wind to the skier, giving him extra air friction. Explain what will happen with the final velocity

Example of SPA+

Question:

- The skier wants to decrease the final velocity, how can he obtain that?

What is the question?	How to obtain a lower v_e ?
Type of question (data, connection or conclusion)	Data has to be changed
Information, data and sketch	m= 80 kg α = 20° k1 = 2,0 kg/m k2 = 0,05  It is the same skier, with the same skies at the same slope. So this means that m, α and k2 don't change
Relevant knowledge/formulas	$F = m.g$ $Fz// = Fz*\sin(\alpha)$ $Fz\perp = Fz*\cos(\alpha)$ $\Sigma F = 0 = F_{wl} + F_{ws} - F_{z//} = 0$ $Fwl = k_1 * v^2$ $Fws = k_2 * Fn$
	(see table below)

Data	Connection	Conclusion
?	$F_{z//}$ and F_{ws} are contant	V_e smaller
	$F_{w,l}$ is constant	
	If $F_{w,l}$ is constant although v_e is smaller this means that k must be larger because $Fwl = k_1 * v^2$ does not change	
Standing straight	k can be made larger by making your surface larger	

Example SPA+

Martinuscollege, jouw plek!

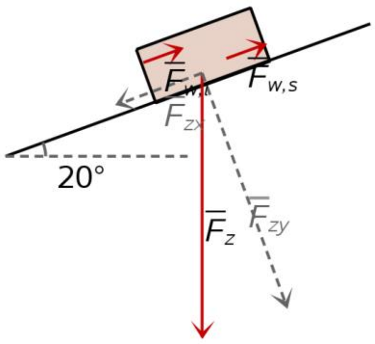
Combining all elements	Conclusion: To make the final velocity smaller it is necessarily to stand up more straight. Connection: The skier is at the same slope with the same skies, so the component of the gravity along and perpendicular to the slope and the kinetic friction stays the same. This means that also the air friction must stay the same because $F_{z//} = F_{ws} + F_{wl}$. With the formula $F_{wl} = k.v^2$. This means that if v must be smaller and F stays the same, this is only possible if k increases. Data: To let k increase the skier must stand up more straight.
Is the answer an answer to the question asked?	" The skier wants to go slower at the end, what can he do to obtain that?" Yes, the answer is an answer to the question

Connection Model and SPA (+)

*SKier.py

```
# Data Sharing
#================================
from ti_system import *
from math import *
#================================

# constants
m = 80  # kg
k1 =1.5 # kg/m
k2=0.05
a=20
g=9.81 # gravitational acceleration

dt = 0.1 #s time step of the simulation
n = 200 #number of steps

# initiation

v=0  # no initial speed
t= 0 # time starts at 0 s
x=0 # distance measured along the slope

xl=[x]
vl=[v]
tl=[t]

for i in range(n):
    # model
    Fzx=m*g*sin(a/360*2*pi)     # calculation of components of the gravity force
    Fzy=m*g*cos(a/360*2*pi)

    Fws=k2*Fzy                  # calculation of the friction forces
    Fwl=k1*v**2

    acc=(Fzx-Fwl-Fws)/m         # calculation of acceleration, new velocity and place
    v=v+acc*dt
    x=x+v*dt
    t=t+dt

    xl.append(x)                # add new values to list for drawing
    vl.append(v)
    tl.append(t)

store_list("xl",xl)
store_list("tl",tl)
store_list("vl",vl)
```

Data and sketch	m= 80 kg α = 20° k1 = 2,0 kg/m k2 = 0,05
Relevant knowledge/formulas	F = m.g Fz//=Fz*sin(α) Fz⊥ = Fz*cos(α) Σ F = 0 $Fwl=k_1*v^2$ $Fws = k_2*Fn$



SPA+ and modelling

$80\cdot 9.81 \blacktriangleright 784.8$

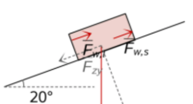
$784.8\cdot \sin(20) \blacktriangleright 268.417$

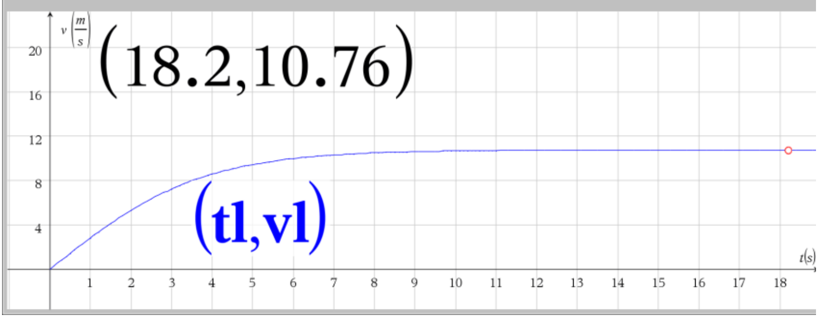
$784.8\cdot \cos(20) \blacktriangleright 737.471$

$737.471\cdot 0.05 \blacktriangleright 36.8736$

$784.8\cdot \sin(20)-36.8736 \blacktriangleright 231.544$

$\sqrt{\frac{231.544}{2}} \blacktriangleright 10.7597$

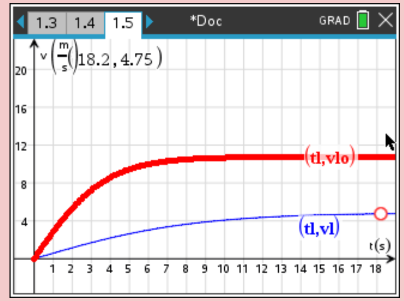
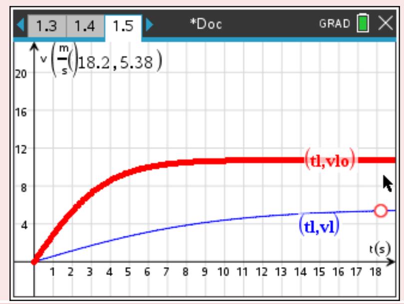
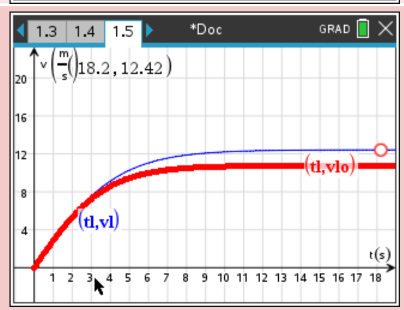




*SKier.py

```python
# Data Sharing
#=================================
from ti_system import *
from math import *
#=================================

# constants
m = 80  # kg
k1 =1.5 # kg/m
k2=0.05
a=20
g=9.81 # gravitational acceleration

dt = 0.1 #s time step of the simulation
n = 200 #number of steps

# initiation

v=0  # no initial speed
t= 0 # time starts at 0 s
x=0 # distance measured along the slope

xl=[x]
vl=[v]
tl=[t]

for i in range(n):
  # model
  Fzx=m*g*sin(a/360*2*pi)      # calculation of components of the gravity force
  Fzy=m*g*cos(a/360*2*pi)

  Fws=k2*Fzy                   # calculation of the friction forces
  Fwl=k1*v**2

  acc=(Fzx-Fwl-Fws)/m          # calculation of acceleration, new velocity and place
  v=v+acc*dt
  x=x+v*dt
  t=t+dt

  xl.append(x)                 # add new values to list for drawing
  vl.append(v)
  tl.append(t)

store_list("xl",xl)
store_list("tl",tl)
store_list("vl",vl)
```

Questions and solutions

<table>
<tr><th>Question</th><th></th></tr>
<tr><td>How does the v,t diagram change if the kinetic friction is enlarged? Why?</td><td>
</td></tr>
<tr><td>Assume that the red line are real data points. How do you have to change k1 and k2 to let the model predict the real data? Explain why?</td><td>
</td></tr>
<tr><td>What is changed between the red and the blue model output? Why?</td><td>
</td></tr>
</table>

Conclusion

Martinuscollege, jouw plek!

- SPA (+) is an algorithmic way to give students a strategy to answer:
  - Questions with difficult calculations
  - Questions that ask for explanations

- Calculations with many steps give high memory load giving low understanding

- Using models can help to increase understanding with less memory load

- Combining SPA+ with models make it possible to explore complex situations and learn students to reason.

- Computational thinking can help students with scientific literacy and critical thinking.