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Freudenthal Institute

Computational Thinking & AR

Workshop Summer School for Mathematics Education Utrecht 2022

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[Video computational thinking]

Example CT & MT

231 + 492

(1)

$$\begin{array}{r} 231 \\ 492 \\ \hline \end{array}$$

(2)

$$\begin{array}{r} 231 \\ 492 \\ \hline 3 \end{array}$$

(3)

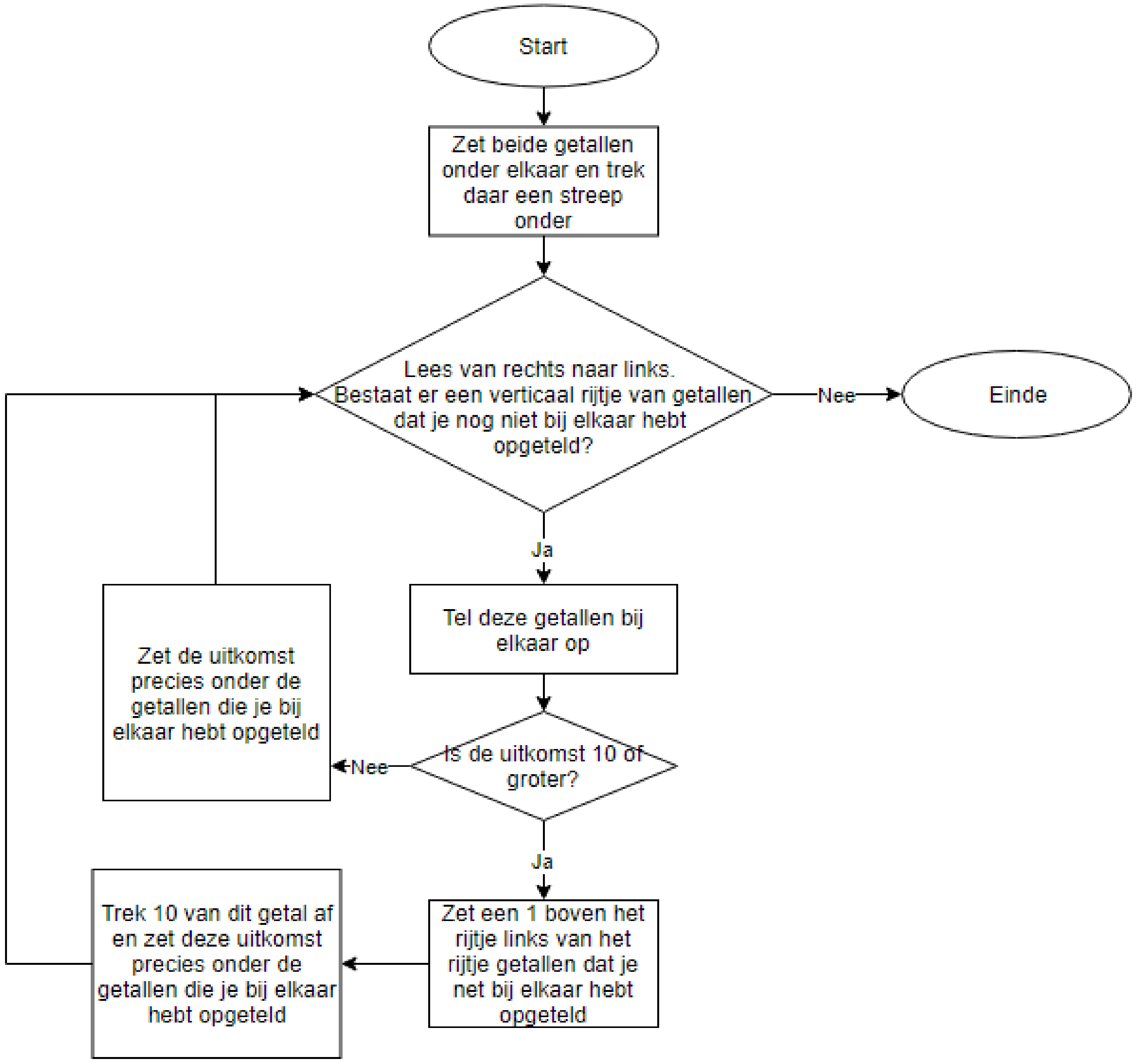
$$\begin{array}{r} 231 \\ 492 \\ \hline 23 \end{array}$$

(4)

$$\begin{array}{r} 1 \\ 231 \\ 492 \\ \hline 23 \end{array}$$

(5)

$$\begin{array}{r} 1 \\ 231 \\ 492 \\ \hline 723 \end{array}$$



Start
Zet beide getallen onder elkaar en trek daar een streep onder
Lees van rechts naar links. Bestaat er een verticaal rijtje van getallen dat je nog niet bij elkaar hebt opgeteld?
Nee
Einde
Ja
Tel deze getallen bij elkaar op
Is de uitkomst 10 of groter?
Nee
Zet de uitkomst precies onder de getallen die je bij elkaar hebt opgeteld
Ja
Zet een 1 boven het rijtje links van het rijtje getallen dat je net bij elkaar hebt opgeteld
Trek 10 van dit getal af en zet deze uitkomst precies onder de getallen die je bij elkaar hebt opgeteld

Content workshop

1. Introduction CT
2. Research
3. Explore CT tasks

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Computational thinking

… is “in the air”

… but is also a “container concept”

Definition Wing (2006)

Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science.

[…] Thinking like a computer scientist means more than being able to program a computer. It requires thinking at multiple levels of abstraction

Definition Lu & Fletcher (2009)

CT involves the thought processes used to understand and phrase problems in such a way that they can be solved in terms of computations.

Not necessarily carried out by a machine.

Operational definition CT (CSTA & ISTE, 2011)

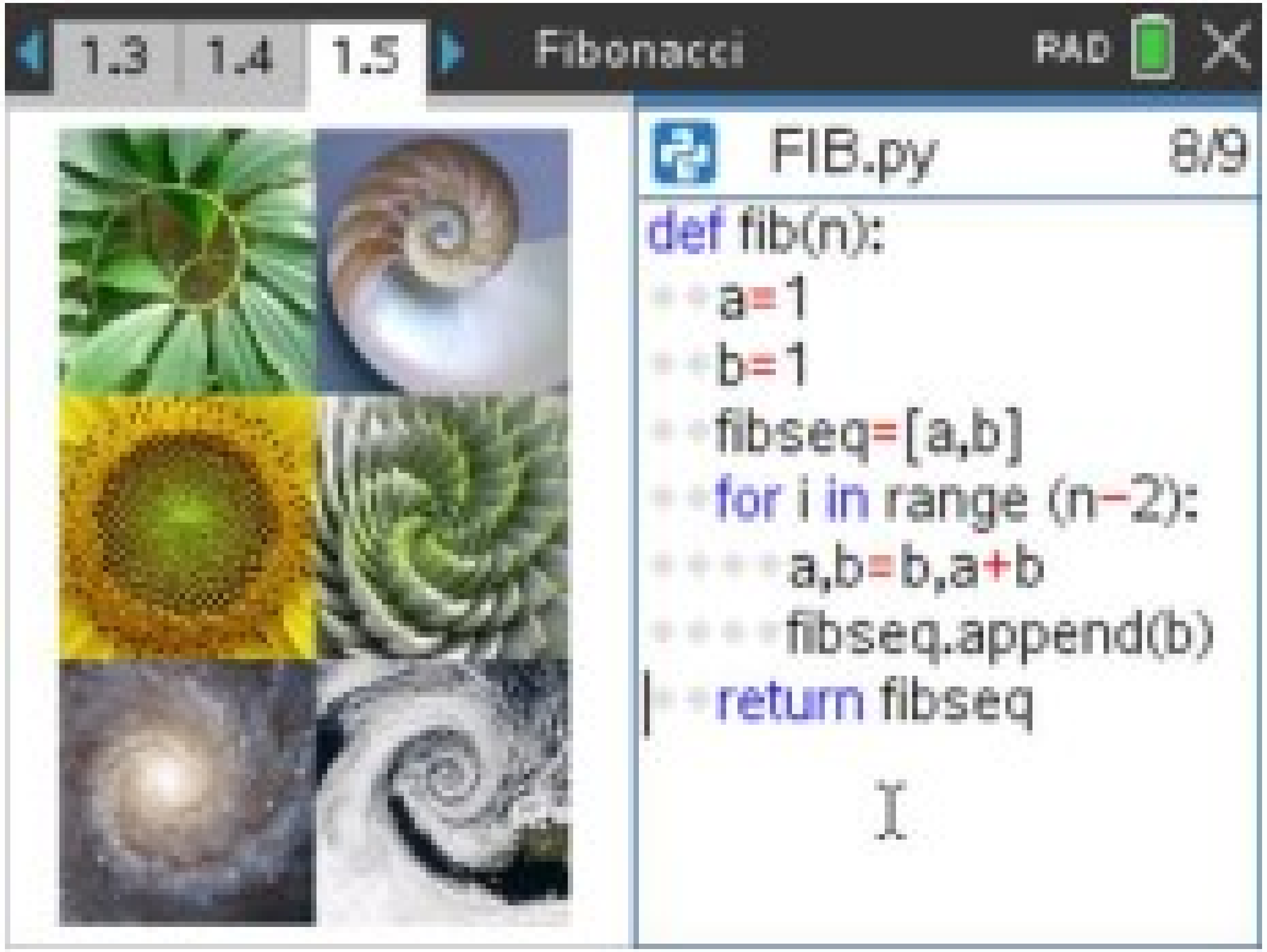
a) formulating problems in a way that enables us to use a computer and other tools to help solve them,
b) logically organising and analysing data,
c) representing data through abstractions such as models and simulations,
d) automating solutions through algorithmic thinking (a series of ordered steps),
e) identifying, analysing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources, and
f) generalising and transferring this problem-solving process to a wide variety of problems.

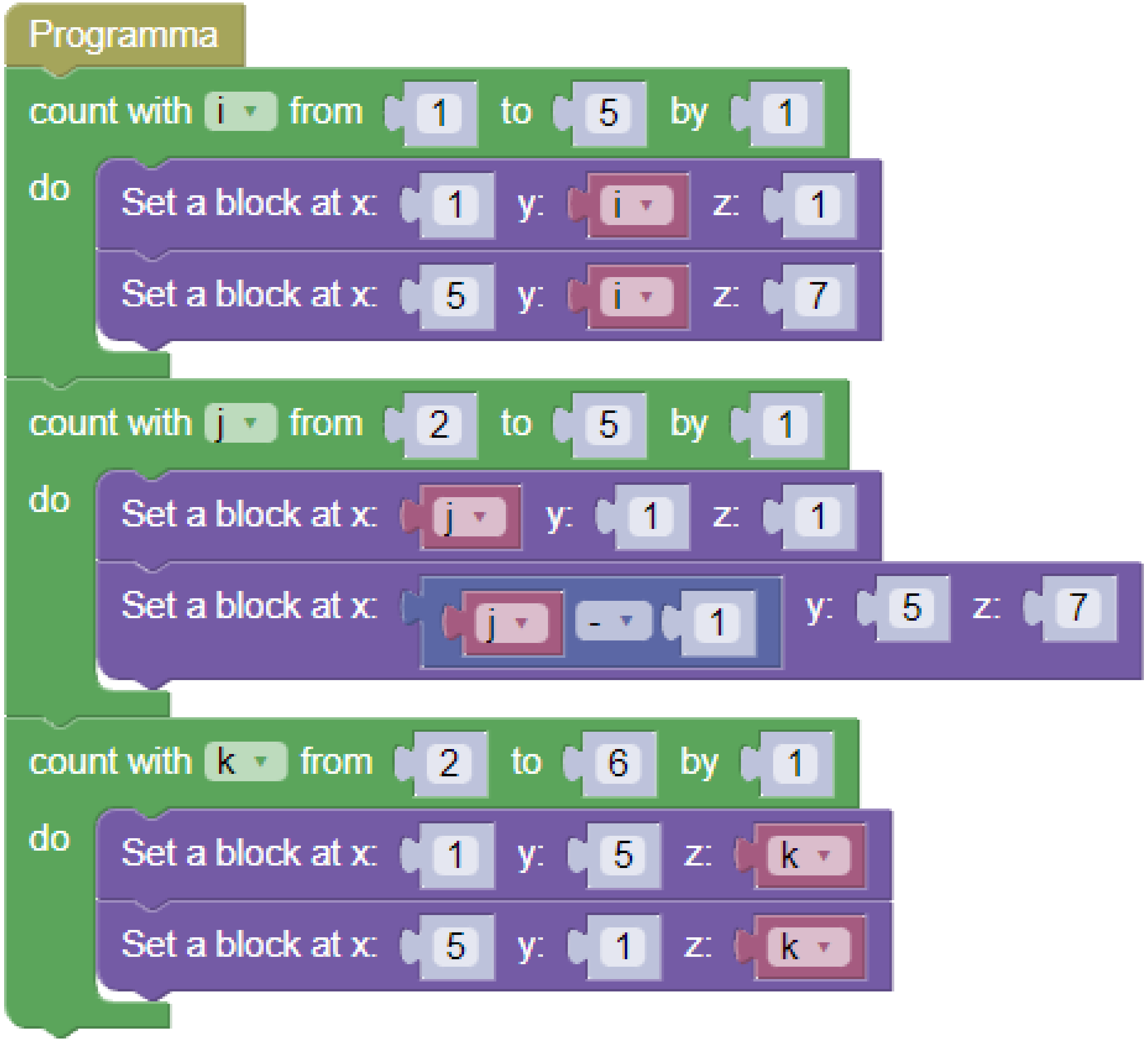
(Computer Science Teachers Association & Intern. Society for Technology in Ed., 2011)

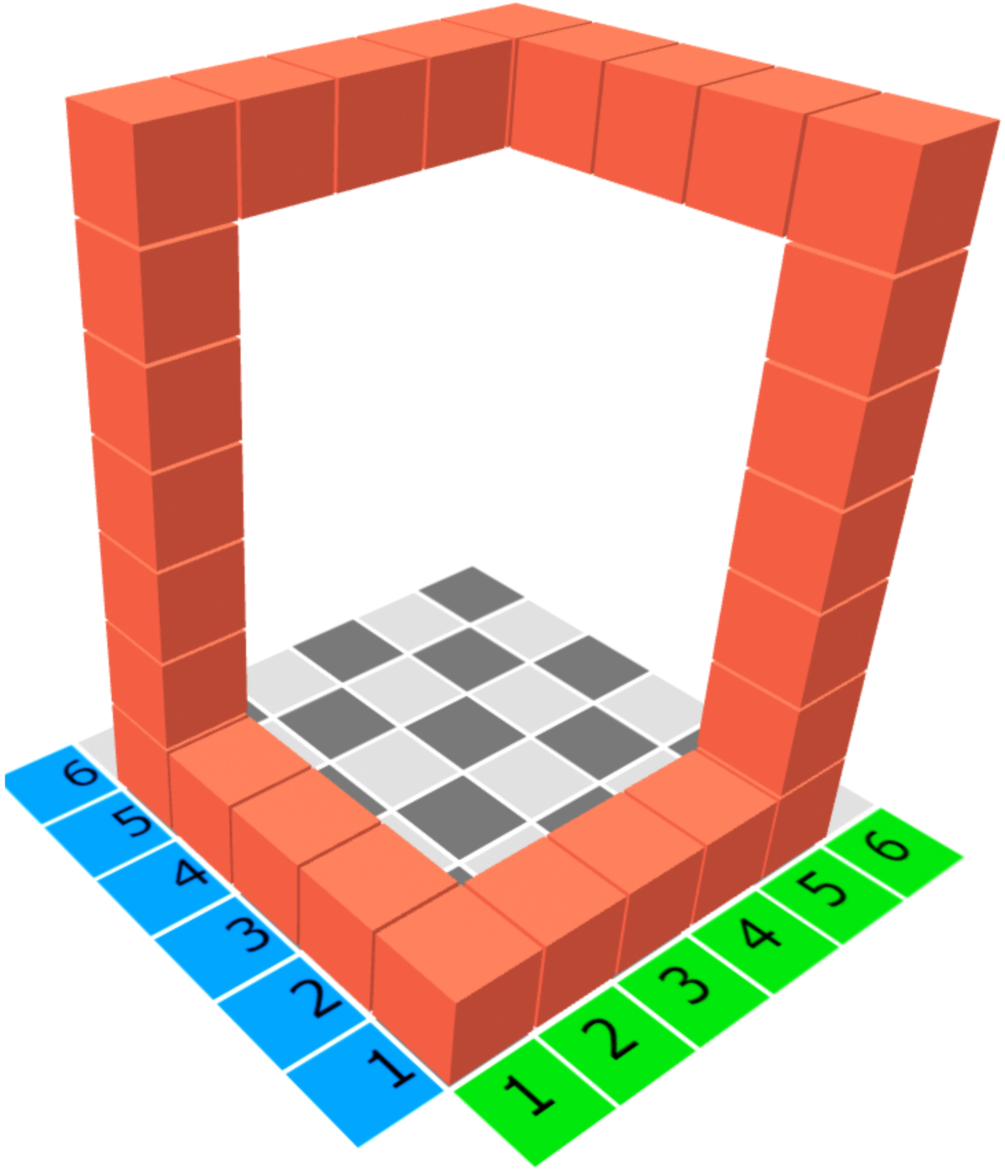
CSTA & ISTE (2011): CT attitude

a) confidence in dealing with complexity,
b) persistence in working with difficult problems,
c) tolerance for ambiguity,
d) the competence to deal with open-ended problems,
e) the capability to communicate and work with others to achieve a common goal or solution.

Programming




Programma
count with i from 1 to 5 by 1
do
Set a block at x: 1 y: i z: 1
Set a block at x: 5 y: i z: 7
count with j from 2 to 5 by 1
do
Set a block at x: j y: 1 z: 1
Set a block at x: j - 1 y: 5 z: 7
count with k from 2 to 6 by 1
do
Set a block at x: 1 y: 5 z: k
Set a block at x: 5 y: 1 z: k


6
5
4
3
2
1
1
2
3
4
5
6

05 Programs for building with blocks

If a series of building commands shows regularity, you can use variables to shorten the program.

build	1,2,5
build	2,2,5
build	3,2,5
build	4,2,5
build	5,2,5
build	6,2,5
build	7,2,5
build	8,2,5

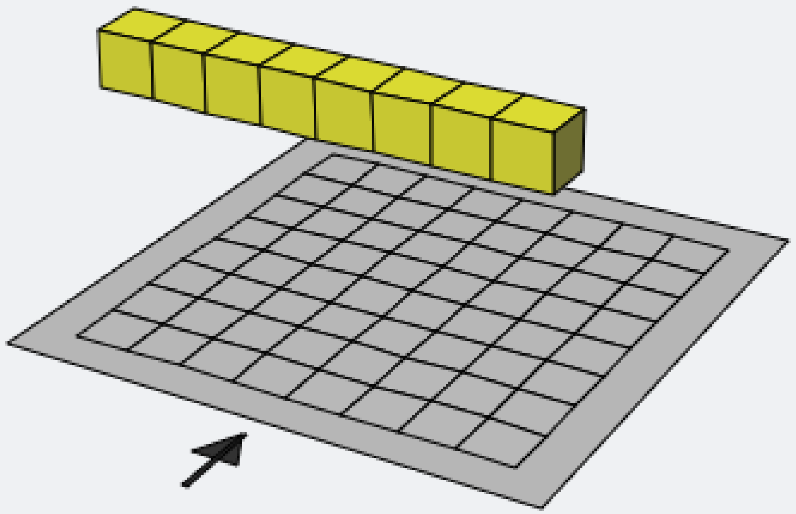
build	1,2,5
build	2,2,5
build	3,2,5
build	4,2,5
build	5,2,5
build	6,2,5
build	7,2,5
build	8,2,5

```
a = 1..8
build a,2,5
```

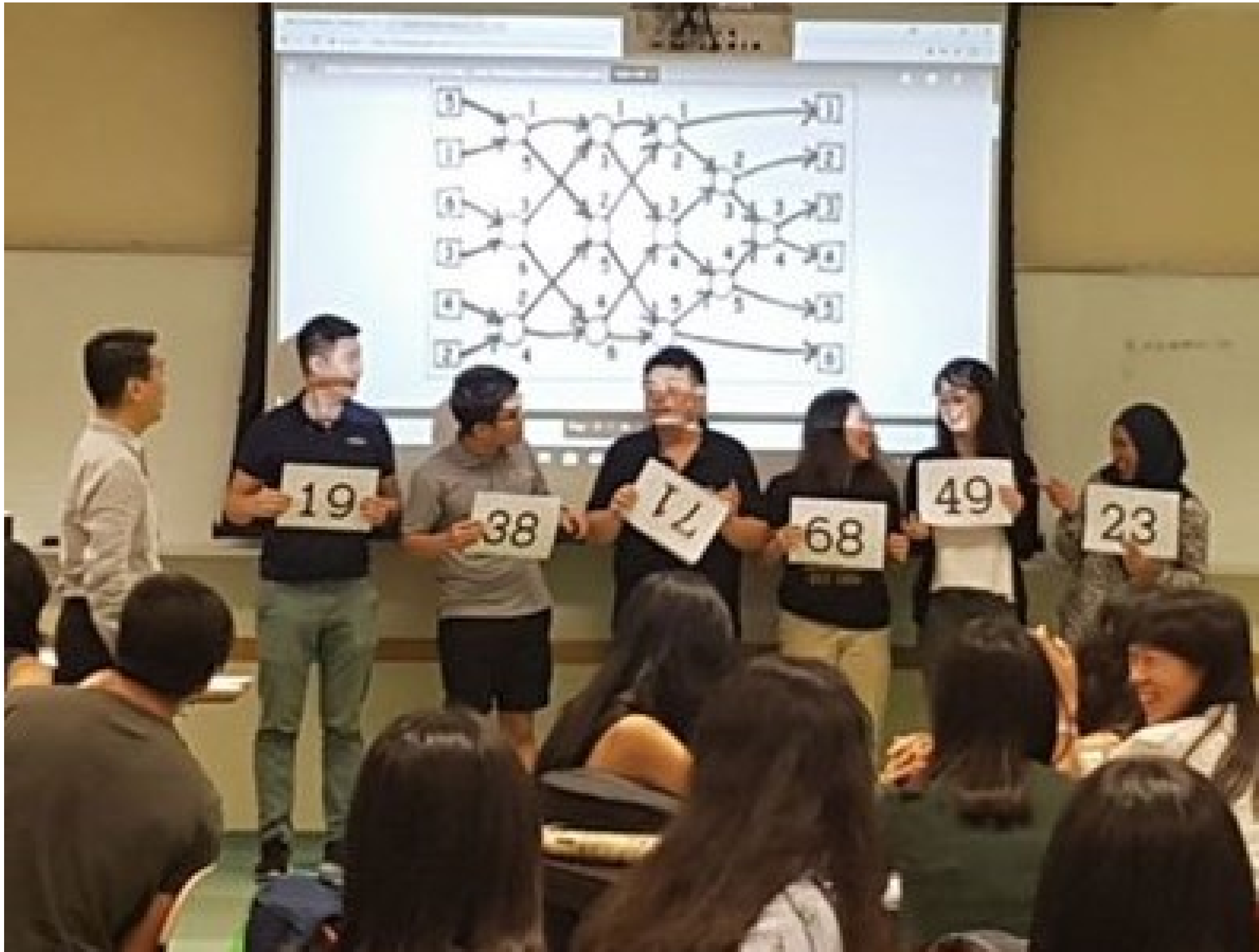
Program

```
a=1..8
build a,2,5
```

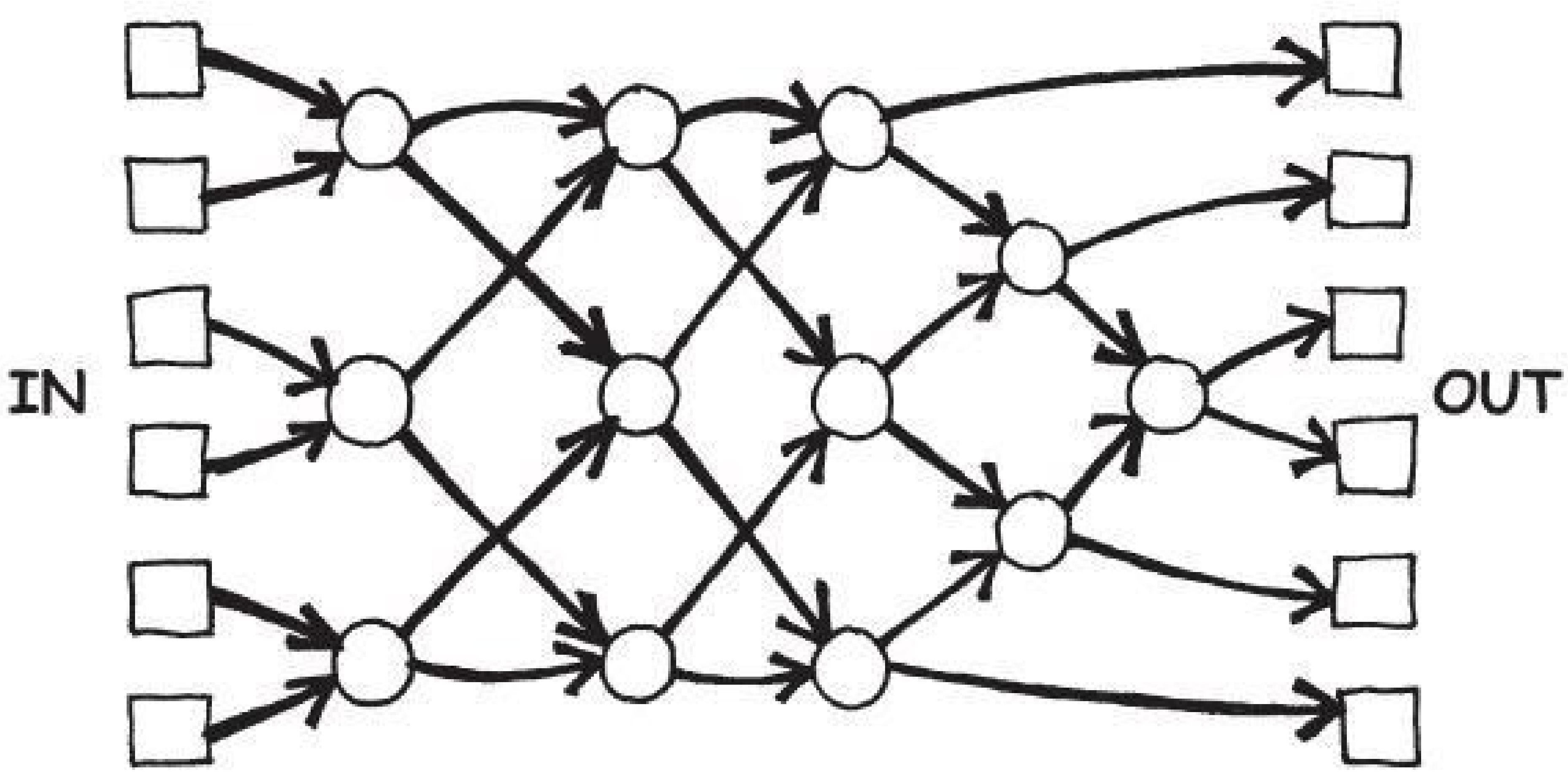
Execute



Unplugged



Unplugged



CT using digital tools

Excel
GeoGebra
…

Content workshop

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Research project CT & MT

- Computational thinking in the mathematics curriculum
- Three-year project
- Context: 11th grade pre-university students

Collaboration

Utrecht University

Radboud University

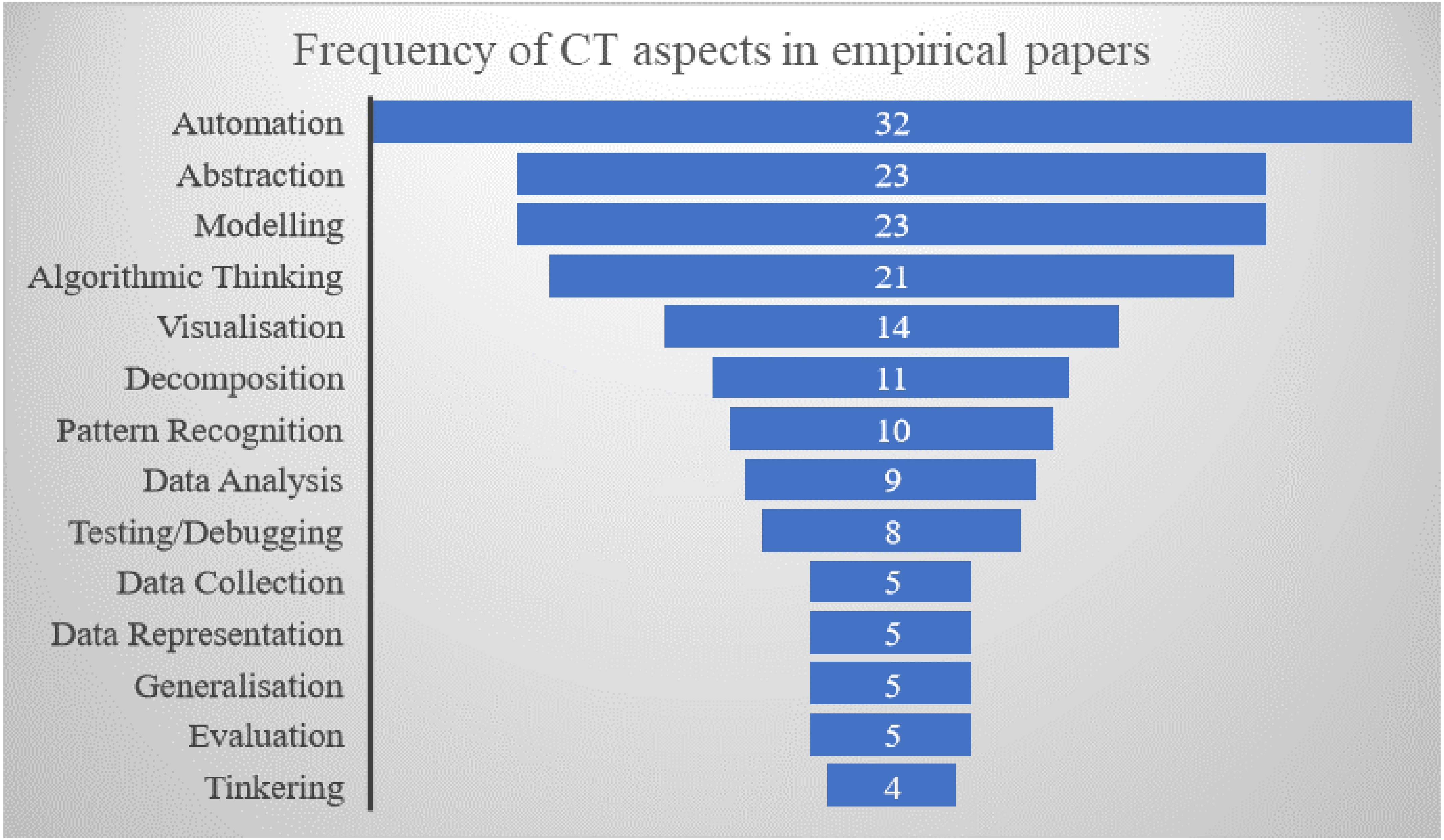
SLO

Five schools

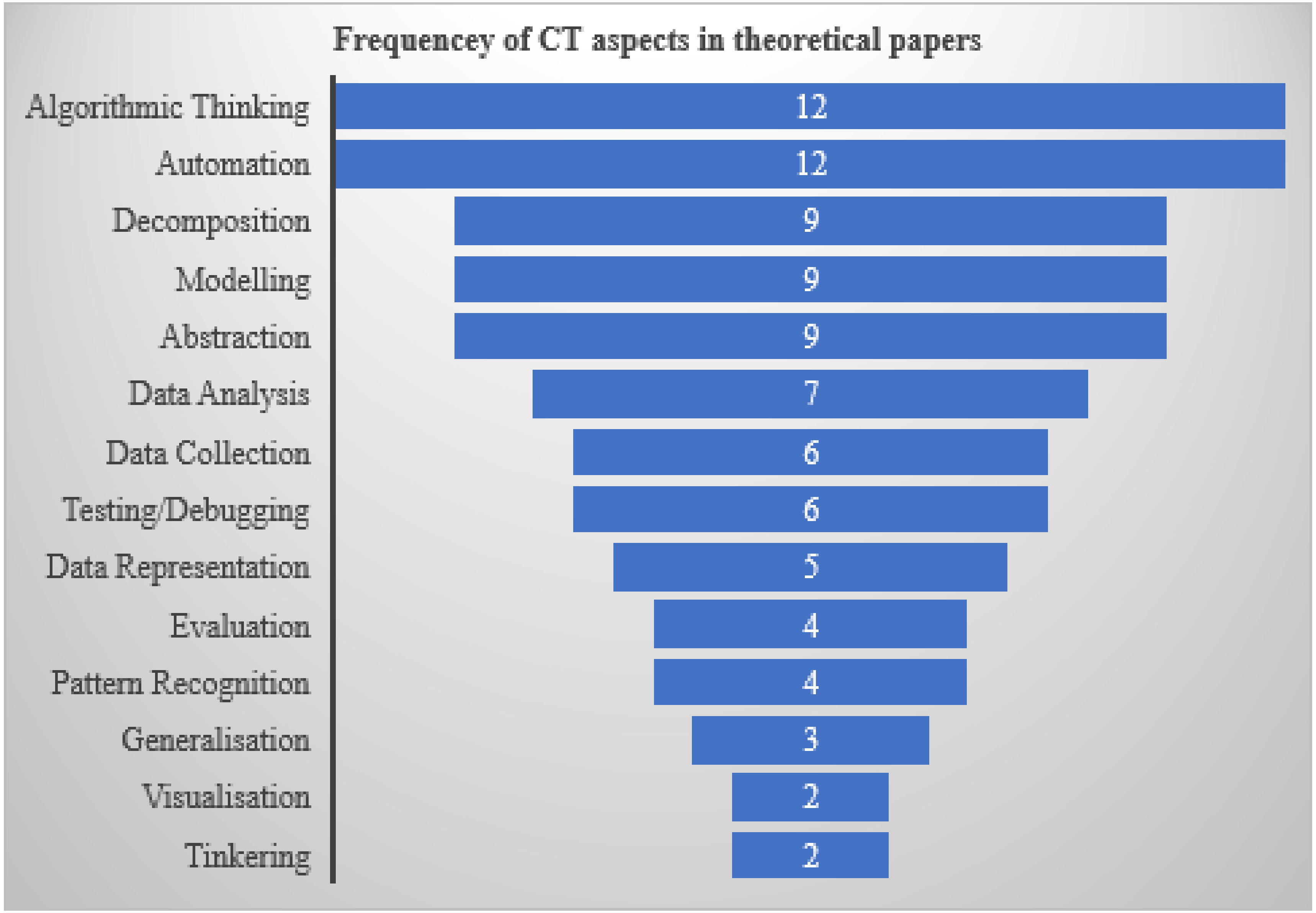
Financed by the Netherlands Initiative for Education Research (NRO)

Research Question

How can a teaching-learning strategy, focusing on the use of digital tools, support 16-17 years old pre-university students in developing computational thinking skills related to mathematical thinking in pure and applied mathematics courses?



Frequency of CT aspects in empirical papers
Automation
32
Abstraction
23
Modelling
23
Algorithmic Thinking
21
Visualisation
14
Decomposition
11
Pattern Recognition
10
Data Analysis
9
Testing/Debugging
8
Data Collection
5
Data Representation
5
Generalisation
5
Evaluation
5
Tinkering
4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9
Modelling
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Abstraction
9
Data Analysis
7
Data Collection
6
Testing/Debugging
6
Data Representation
5
Evaluation
4
Pattern Recognition
4
Generalisation
3
Visualisation
2
Tinkering
2

Interviews teachers

7 teachers

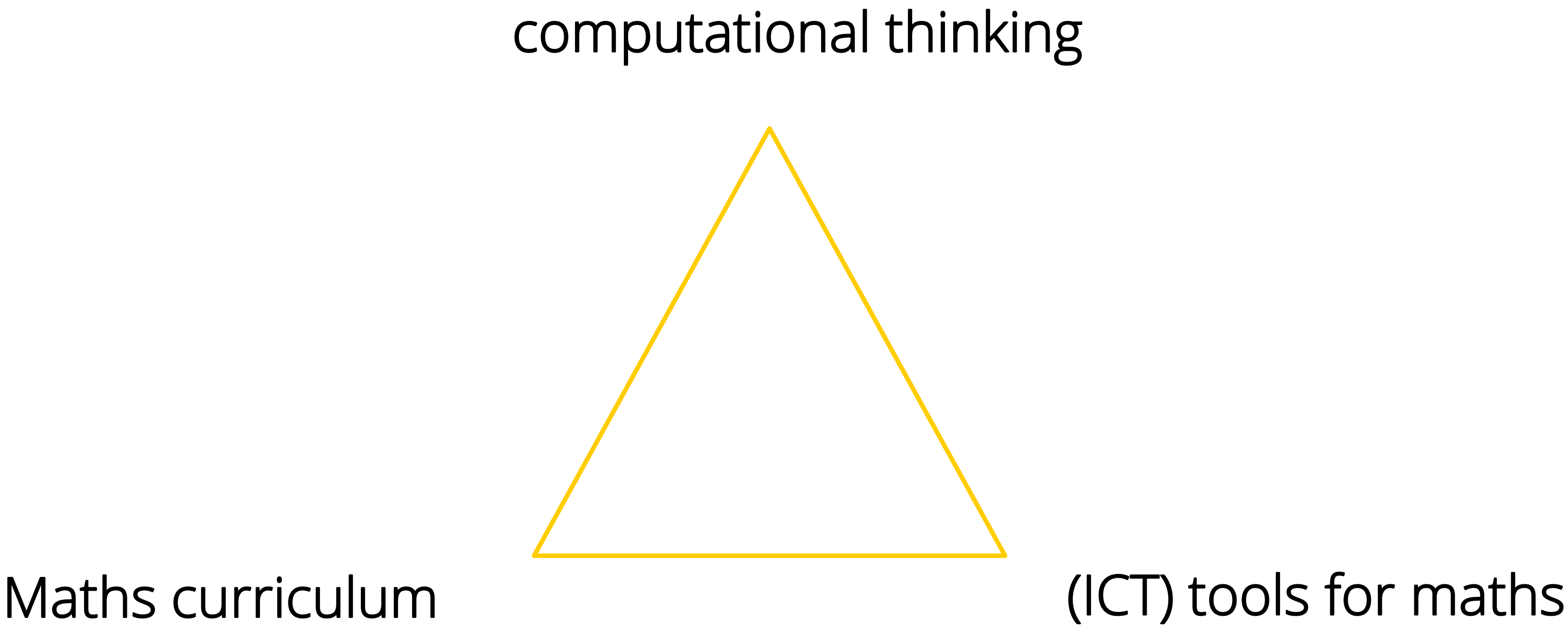
Semi-structured with questions about:

- ideas on aspects of CT
- relation CT & MT
- CT in own teaching practice
- digital tools and programming

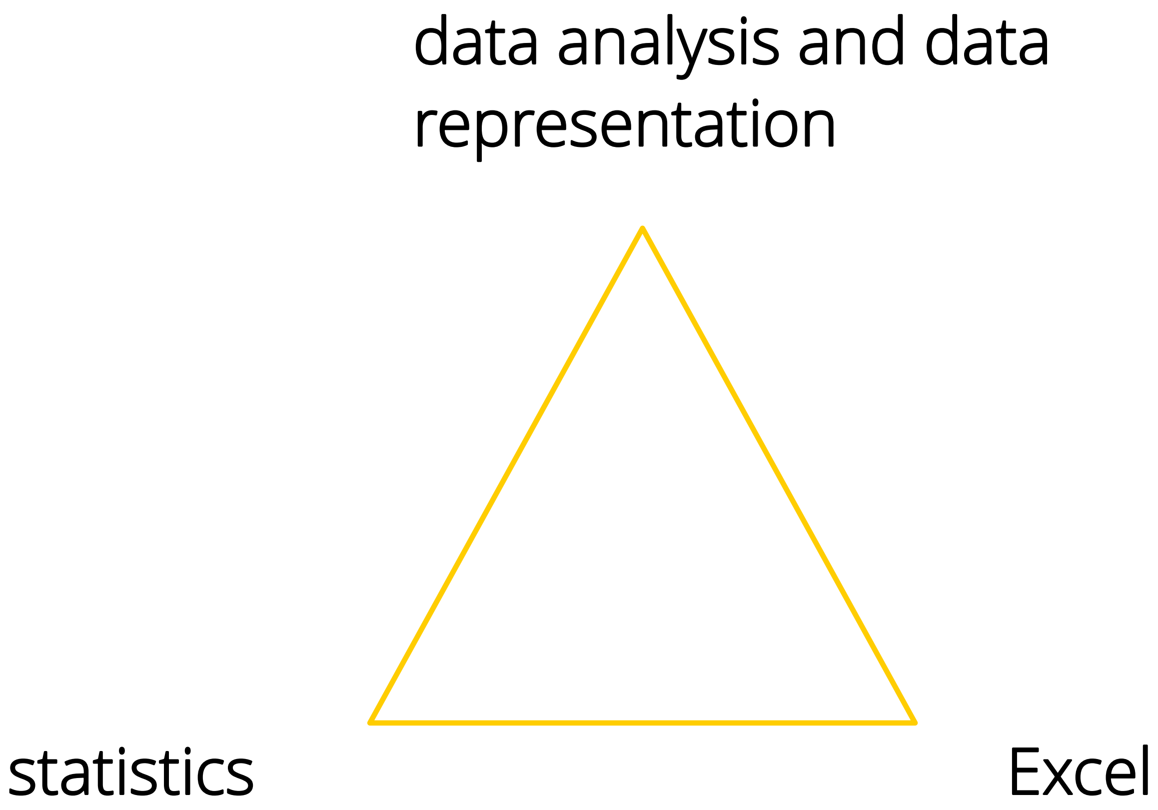
Themes in interviews

- Aspects from Delphi study are relevant and important.
- CT and MT are closely related.
- Need for examples.
- It requires extra time.
- Programming is useful but outside of mathematics class.
- The exams should include CT.

Design lesson series



Mathematics A (applied)

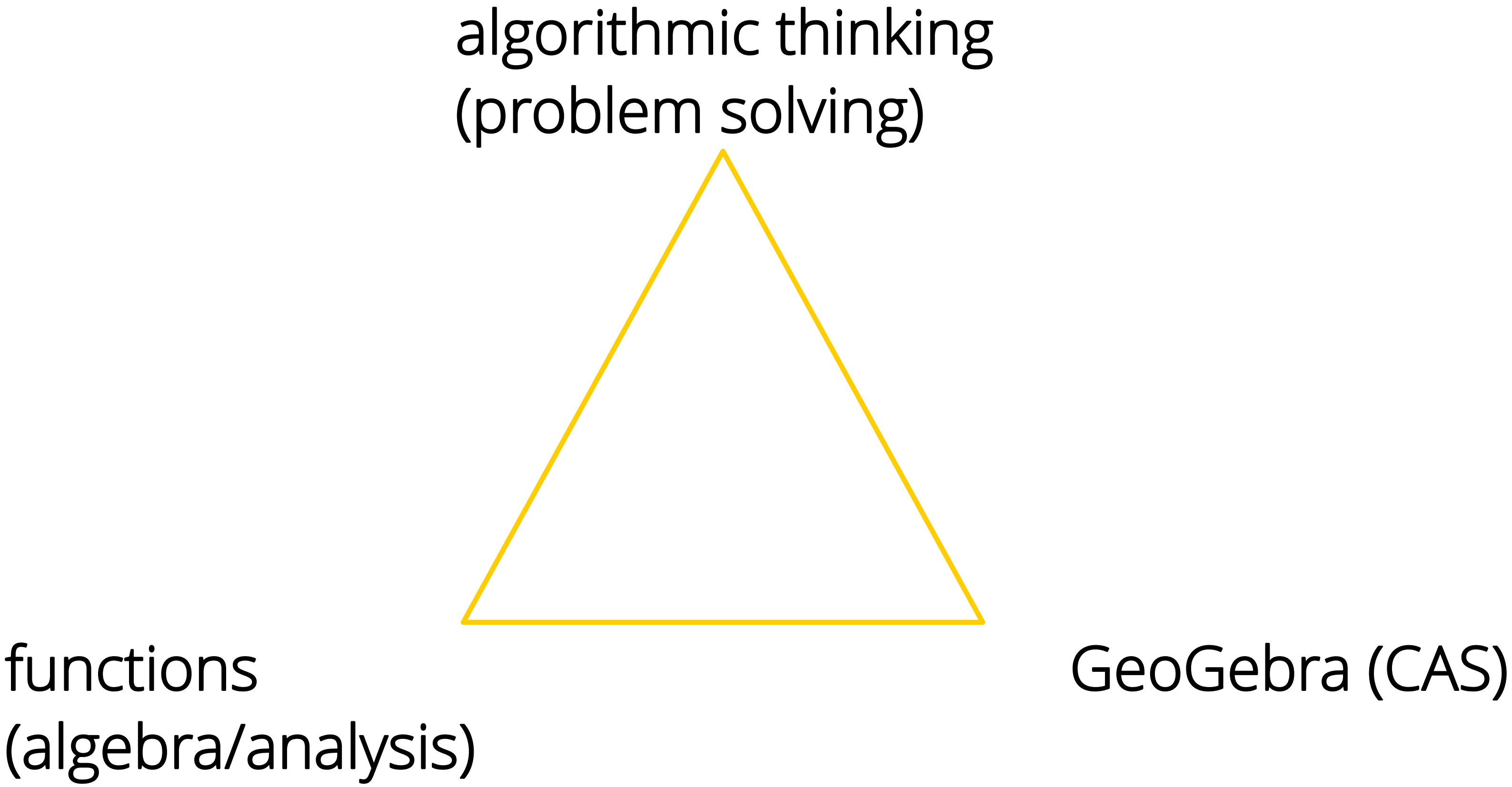


Design lesson series statistics

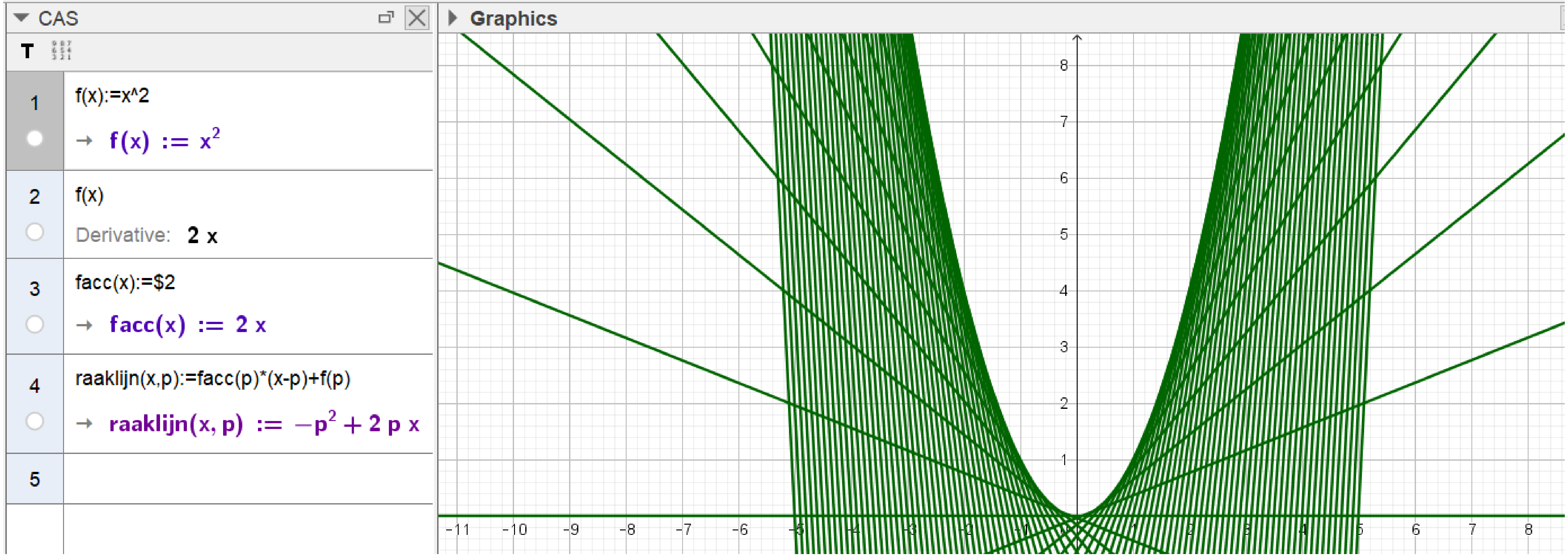
Titanic: “Women and children first?”

- Define research (sub)questions (decomposition)
- Data moves (Erickson et al, 2019): Explore dataset, prepare for analysis, represent, use Excel formulas
- Evaluate results

Mathematics B (pure)



Design lesson series functions



Research lesson series math B

- Focus on two aspects:
  - Algorithmic thinking
  - Generalisation

Research questions

- How can AT and generalization aspects be addressed using DMS in 12th-grade calculus lessons?
- What challenges do students encounter in successfully completing AT and generalization tasks using DMS in 12th-grade calculus lessons?

Methods

15 students 11th grade

6 x 45 minutes lessons using GeoGebra

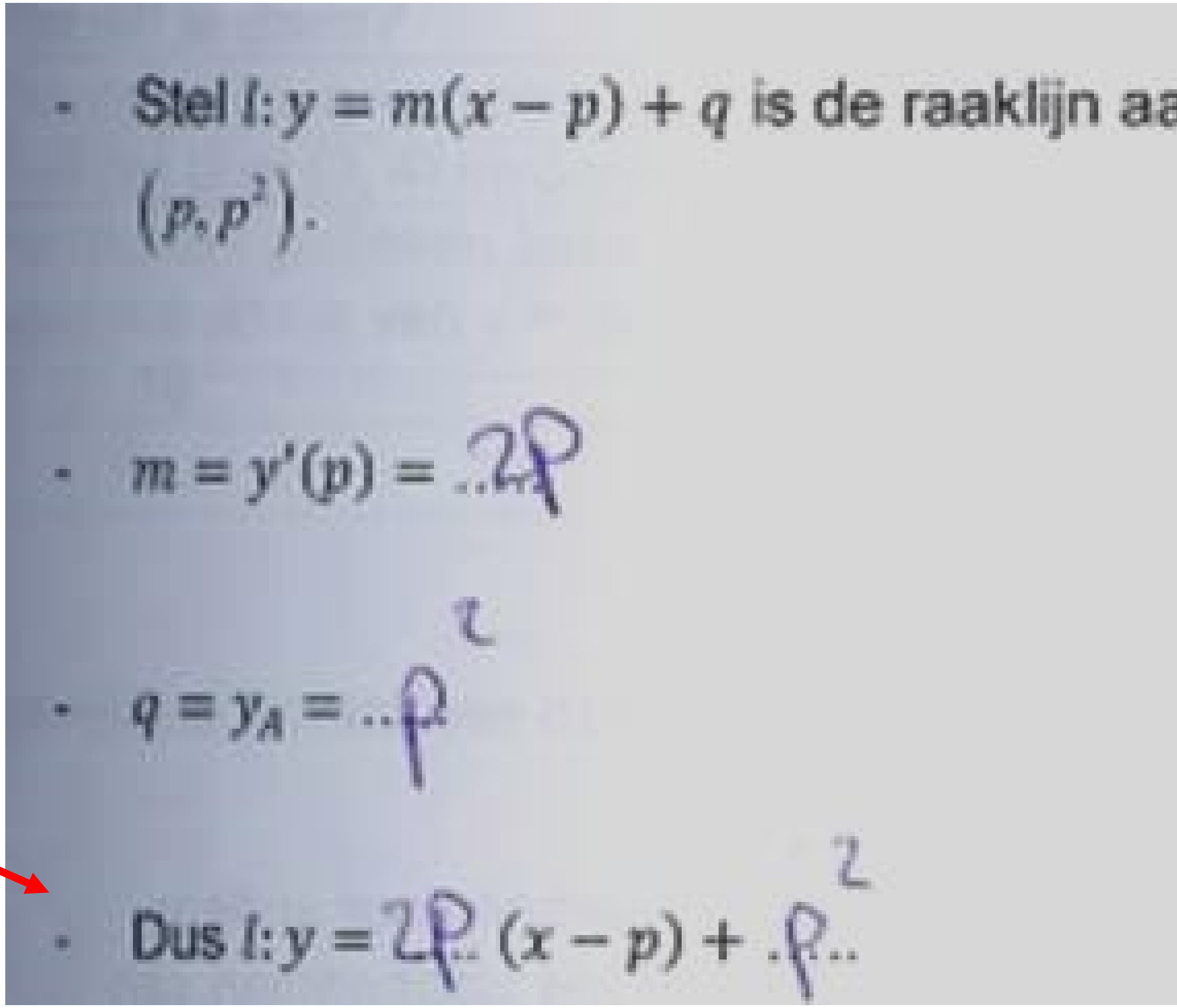
Data:

- Student workbooks
- Student GeoGebra files
- Student interviews
- Notes teacher

Snapshot Workbook

General procedure for defining a tangent line

- **Unplugged**
- ***Generalisation***
- ***Stepwise design***
- ***Object definition***



- Stel $l: y = m(x-p)+q$ is de raaklijn aa
  (p, p^2).
- $m = y'(p) = ..2p$
- $q = y_A = ..p^2$
- Dus $l: y = 2p..(x-p) + .p^2..$

Generalisation

Structure and syntax: conditions

Snapshot GeoGebra

General dynamic perpendicular bisector

Object definition

$M = (0.5\,(x(A)+x(B)), 0.5\,(y(A)+y(B)))$

$\rightarrow (2.5, 2)$

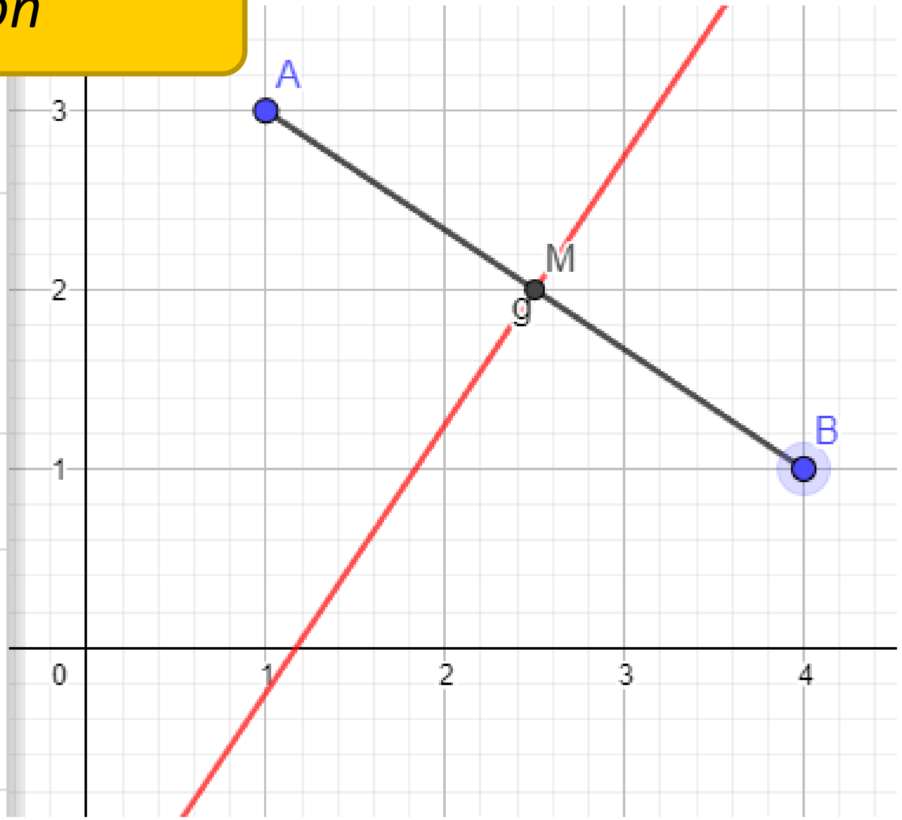
$$a = -\frac{x(B)-x(A)}{y(B)-y(A)}$$

≈ 1.5

$h: y = 1.5\,x + 2 - 1.5 \cdot 2.5$

$$p: \text{Als}\left(y(A) \stackrel{?}{=} y(B), x = x(M), y = -\frac{x(B)-x(A)}{y(B)-y(A)}\,x + y(M) + \frac{x(B)-x(A)}{y(B)-y(A)}\,x(M)\right)$$

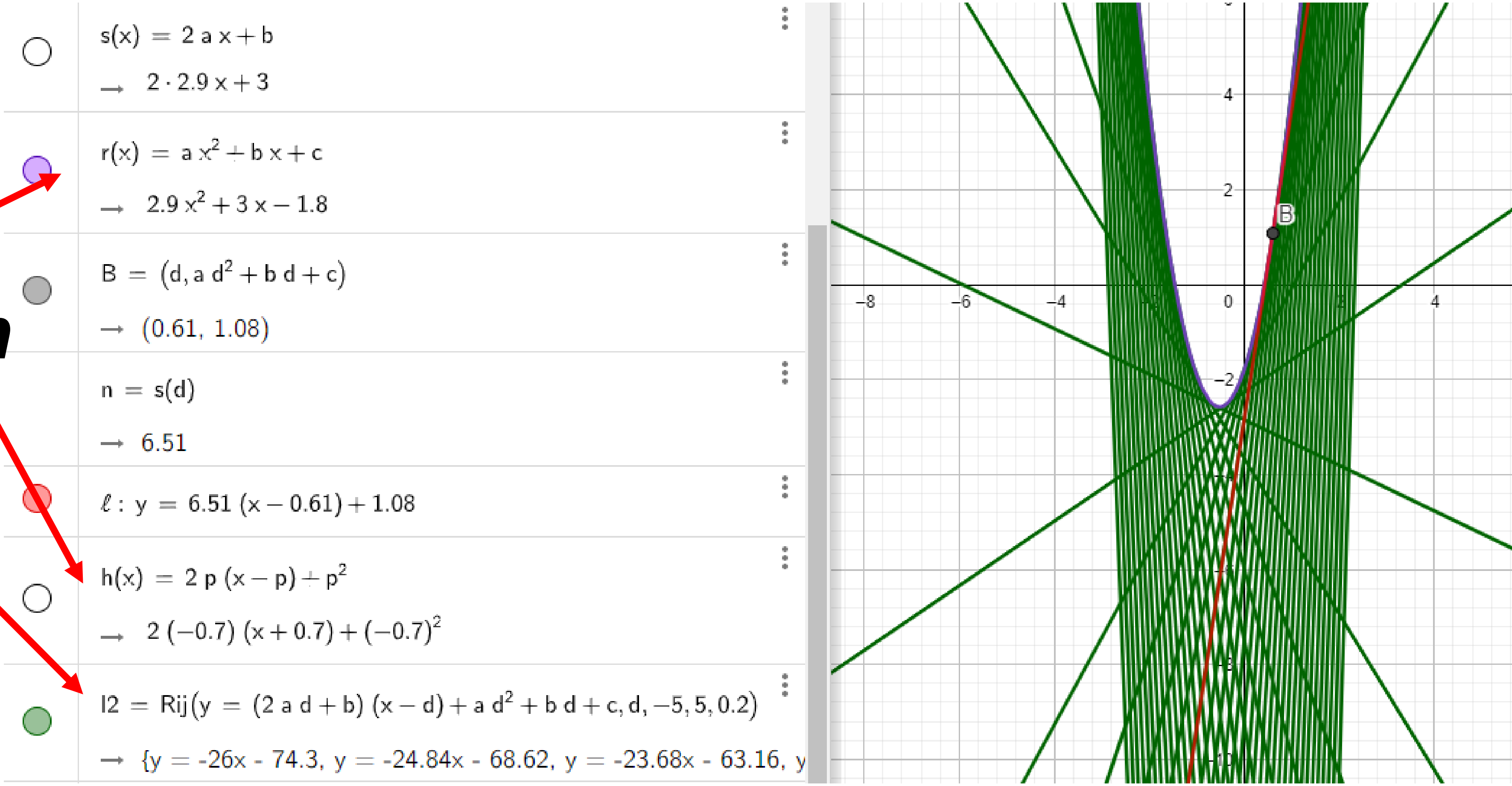
$\rightarrow y = 1.5x - 1.75$



Snapshot GeoGebra file

A series of tangents

- ***Generalisation***
- ***Object definition***
- ***AT: Iteration***



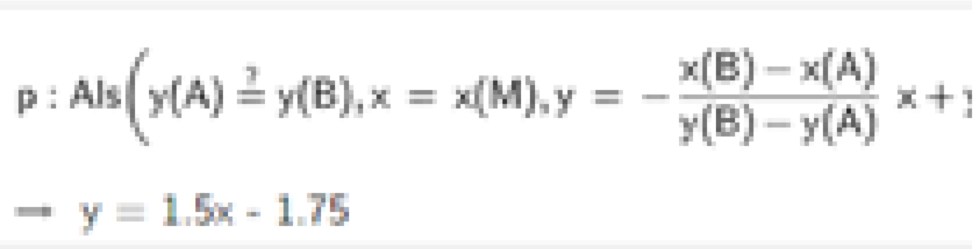
Results interviews – Students about AT and generalisation

- "(Writing down your steps) is easier than doing everything at once in GeoGebra"
- "I work step by step on the computer (GeoGebra) and then write it down, because then I know it's right"
- "That does make it very difficult for me, because it's not necessarily that I'm bad at math, but I am bad at precision. So then I write it down, not exactly as it should be, and on paper that always goes well because then you arrive at the right answer, but on a computer it goes com-ple-te-ly wrong."

Results – Teacher about AT and generalisation

- Positive impression, great enthousiasm
- Positive about student progress and understanding
- Deeper insight into variables

Quote from teacher logboek:
"Many don't realize that if you define *a*, you can then 'call' *a*. So they just type *a* into the formula again. For a few students this has really been an eye opener: 'Oh, that's handy!'"



Results – Encountered difficulties

- "With if-then, then you had to use two = signs, things like that, and that was something I had to ask before I got out."
- "I get so super-frustrated with this that I've almost thrown the computer 3 times already. ... Then I type one thing wrong and then I don't see what I'm typing wrong and then all of a sudden an area comes up and then I do it three times and three times again an area comes up and then something just goes wrong and then I don't see what goes wrong. And then yes...."
- conditional statements (if-then)

Conclusion

- Students and teacher were positive about the lesson series
- AT and generalisation were fruitfully applied by students
- Plugged & unplugged design was succesful

Difficulties were related to

- software/syntax
- logical reasoning

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Colette

Computational Thinking **L**earning **E**nvironment for **T**eachers in **E**urope

A 21st Century Skill in Education

Project website

Demo of Blockly Tasks

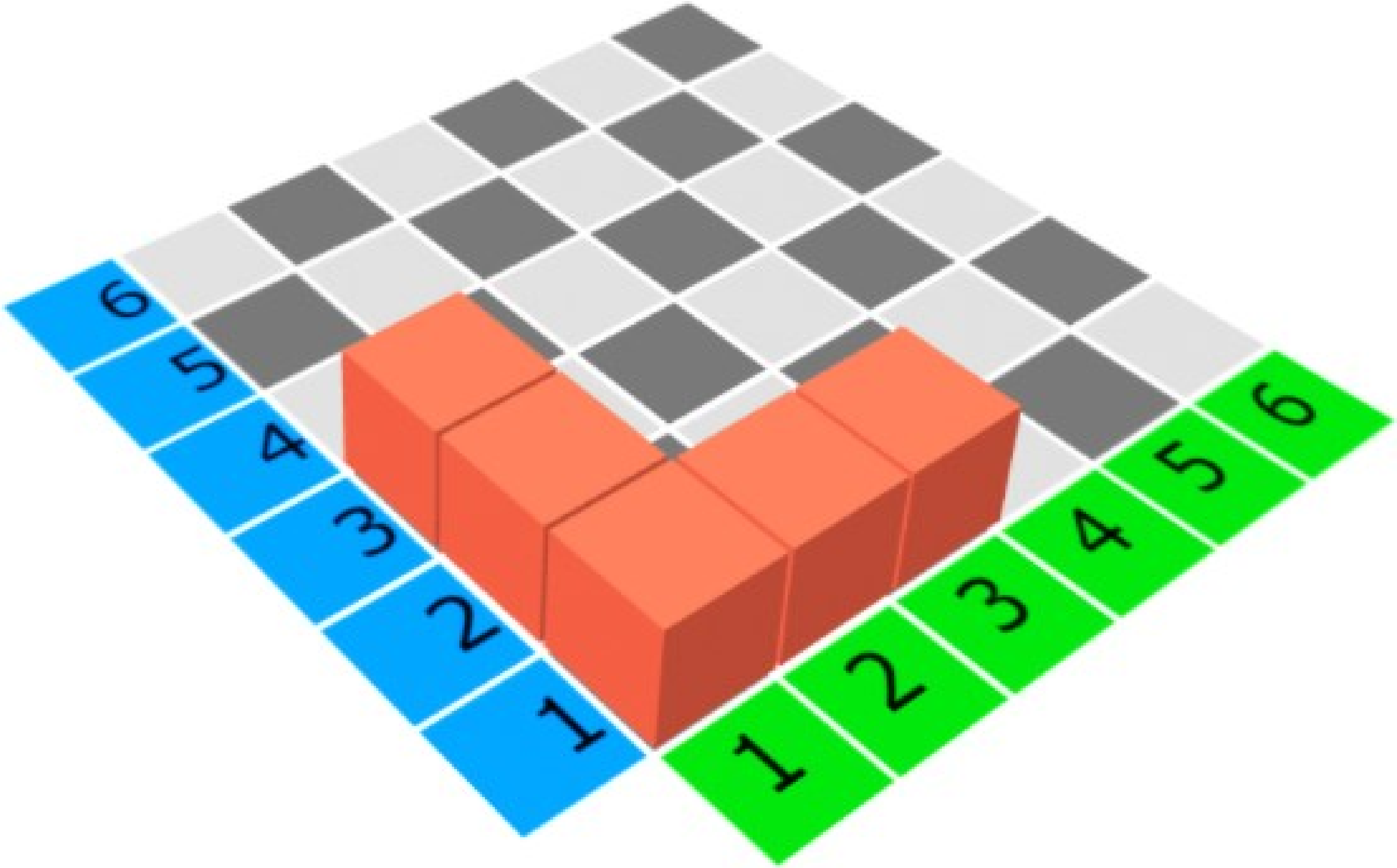
https://colette-project.eu/AR/define_blocks_task1.html

Explore for yourself

Explore the tasks and answer the following questions:

- What CT aspects do you see in these tasks?
- What CT aspects do you think are especially challenging for your students?
- …

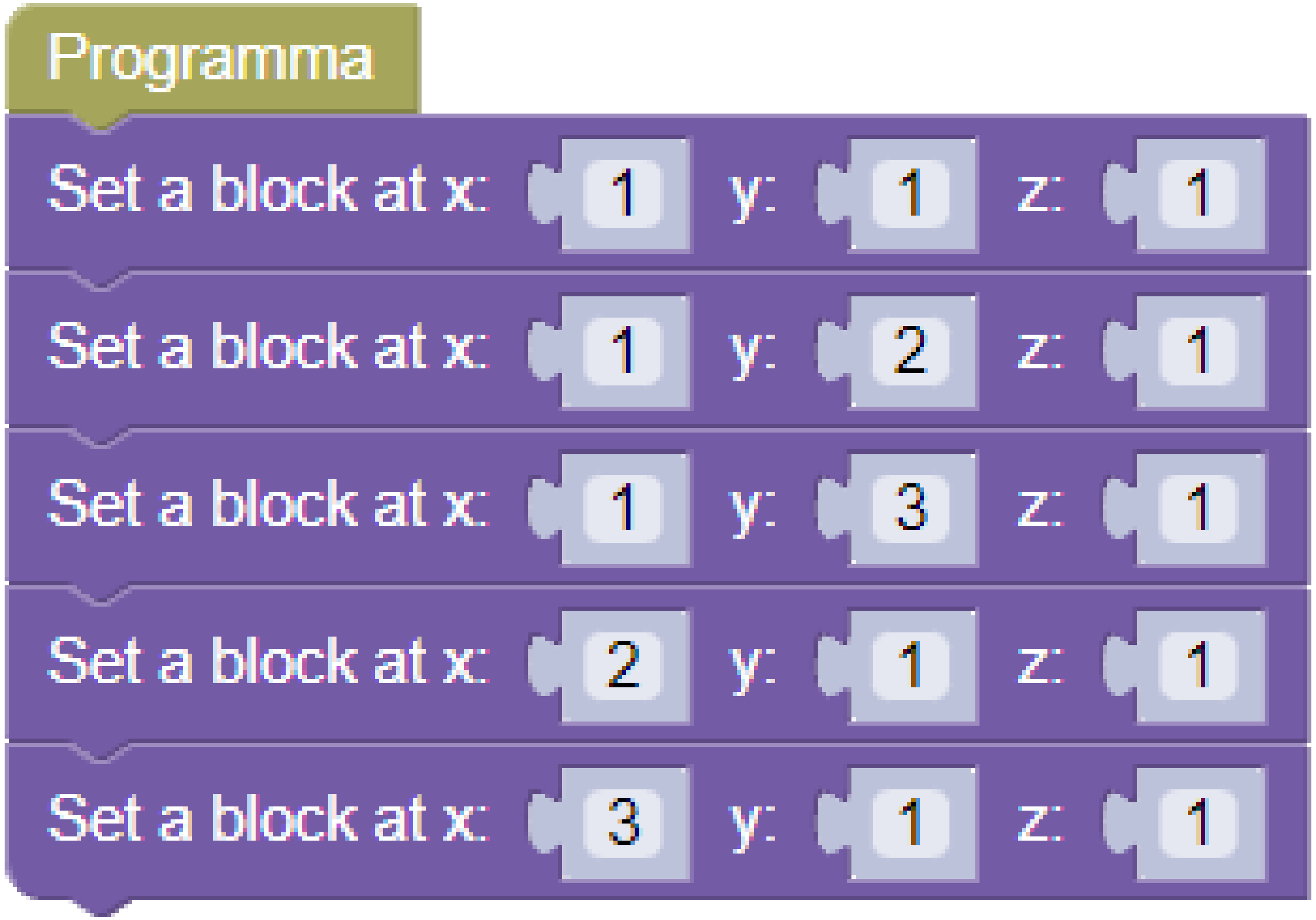
Task 1



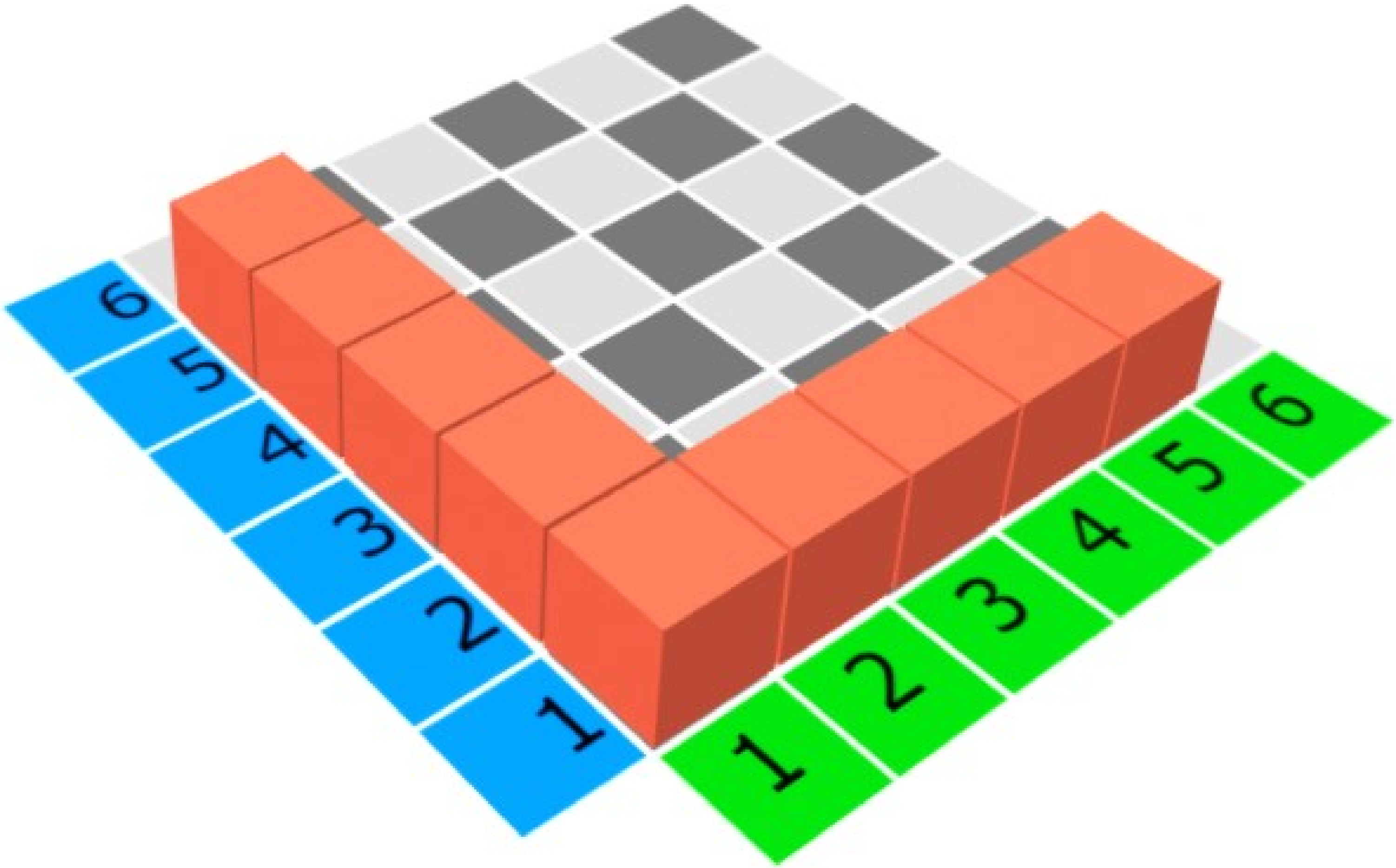
Task 1

- Introduction
- Building cubes
- Hints

Solution task 1



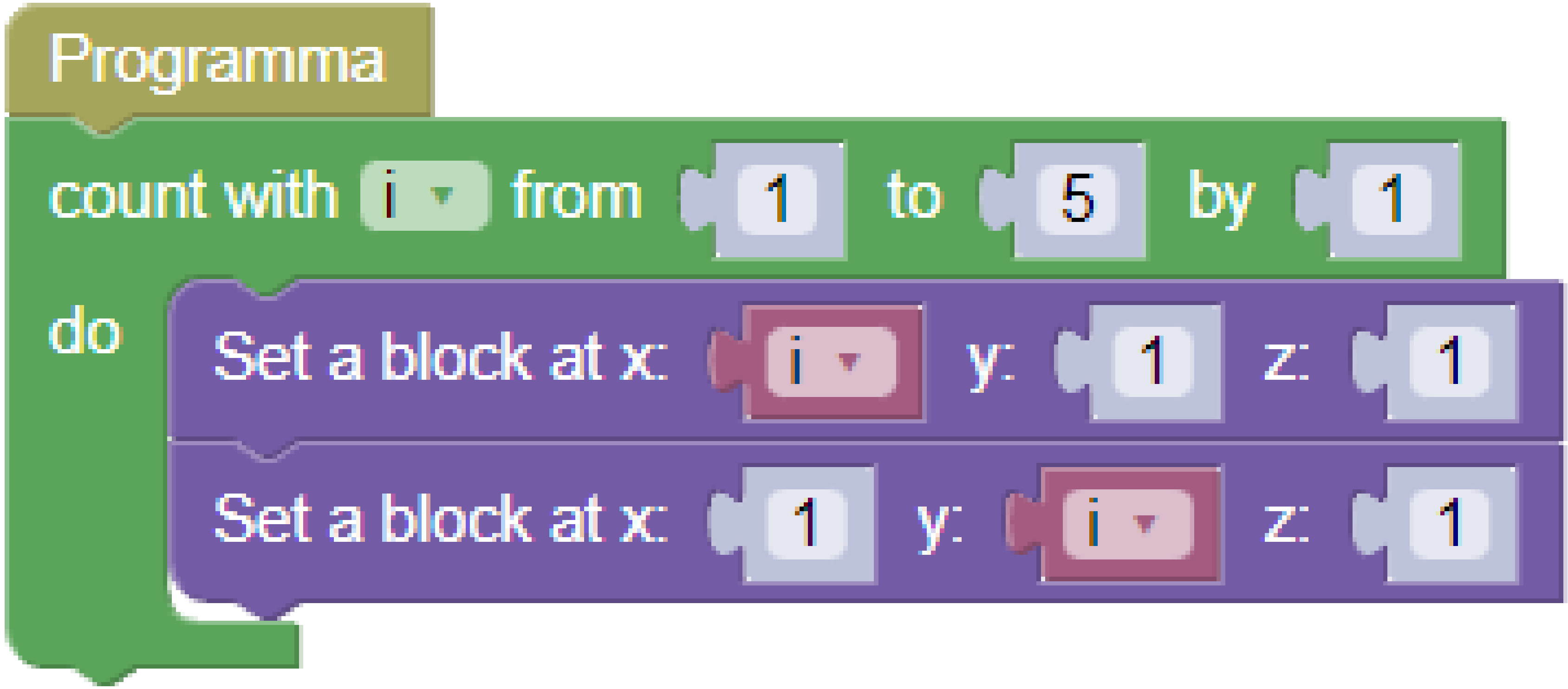
Task 2



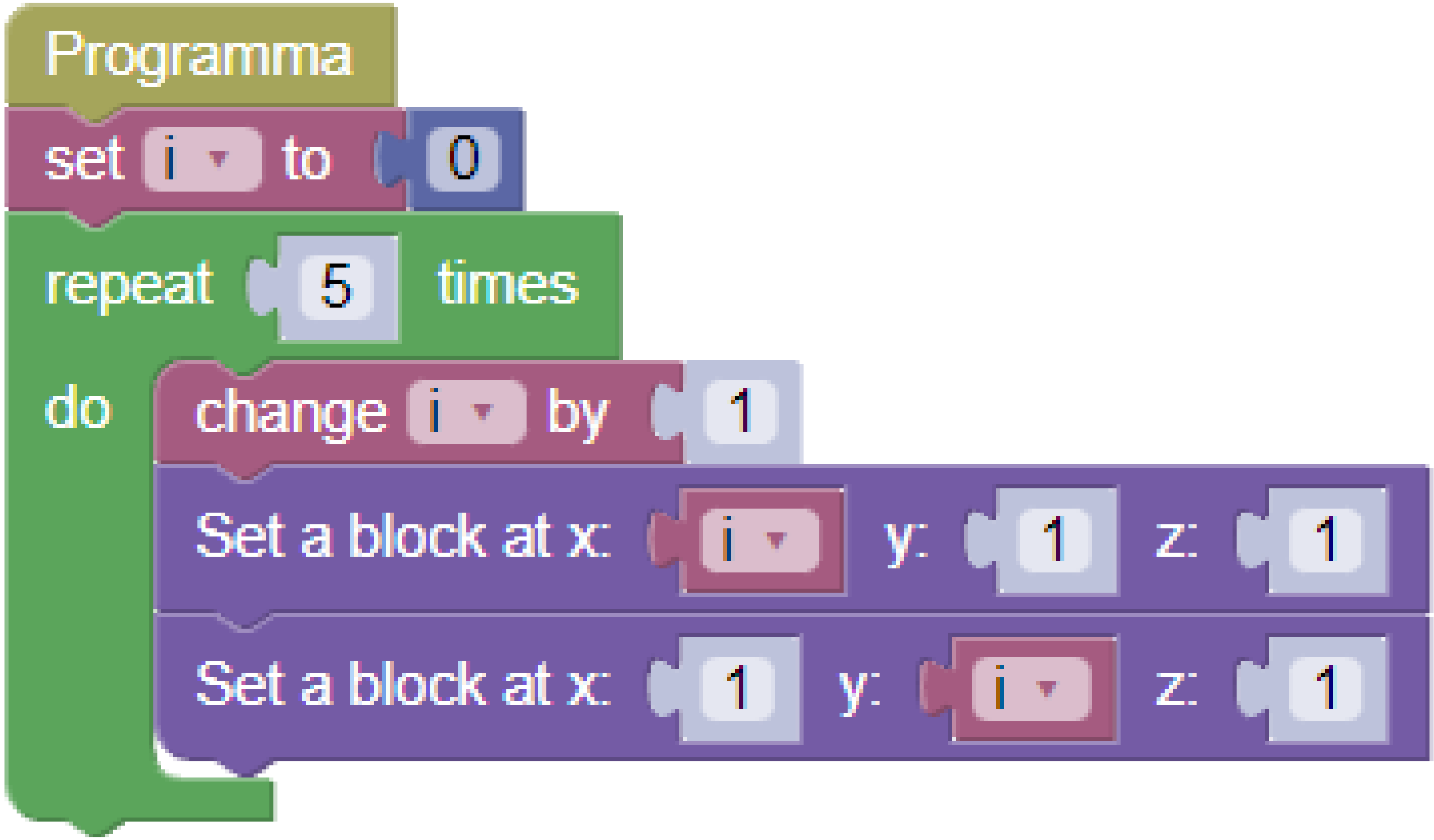
Task 2

- repeat block

Solution task 2

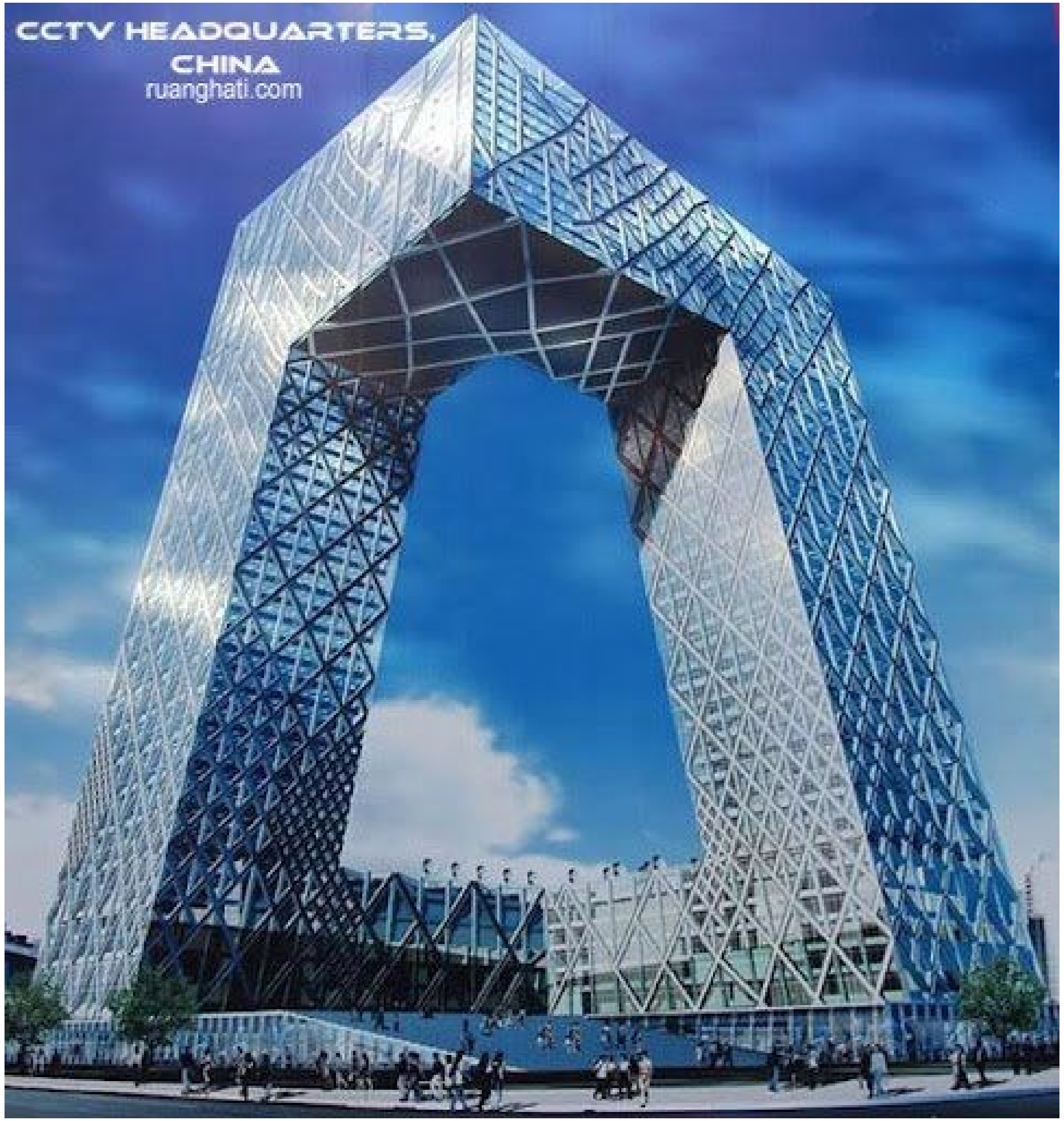


Alternative solution task 2

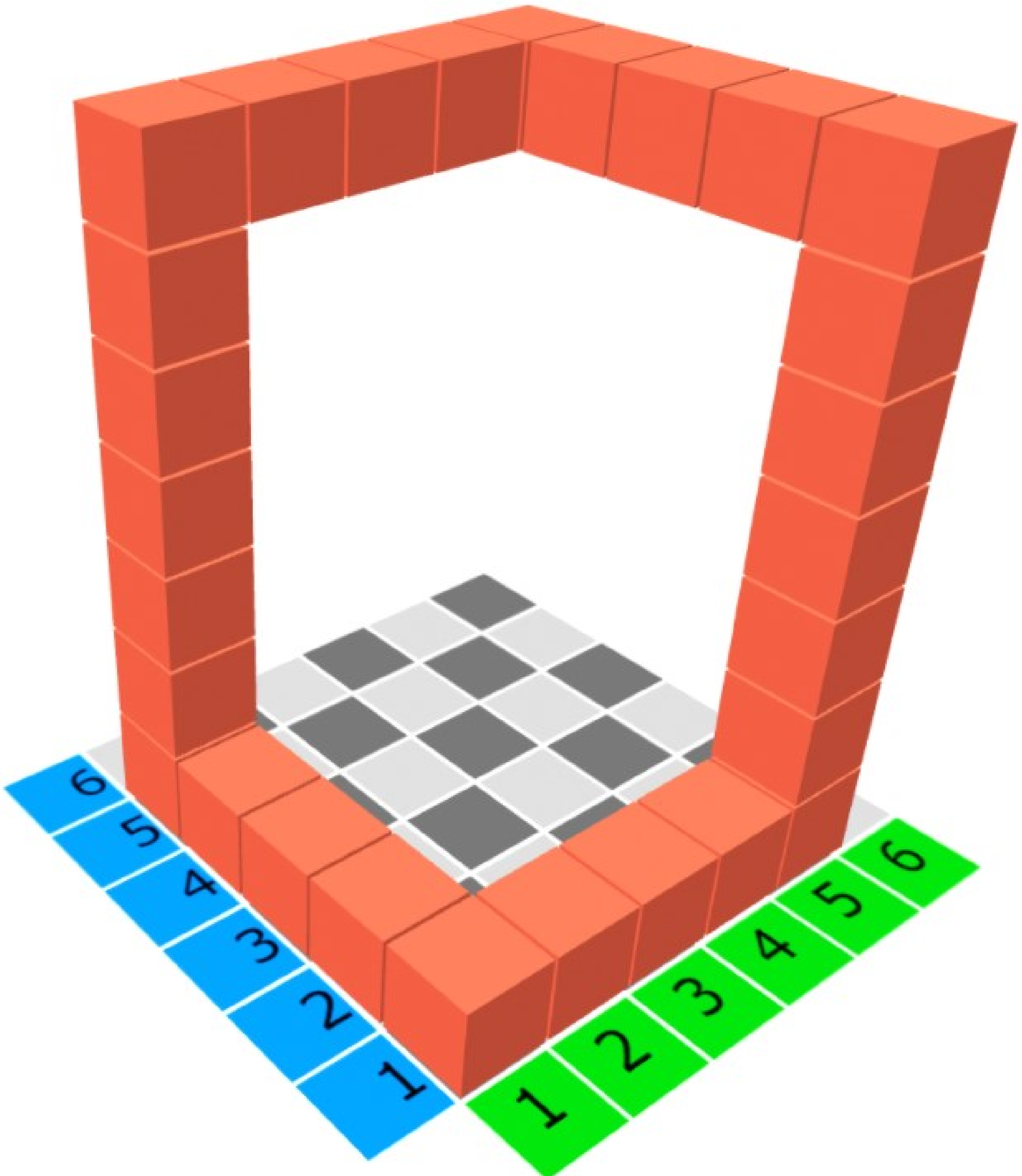


Task 3

CCTV headquarters
in Beijing
by Dutch architect
Rem Koolhaas



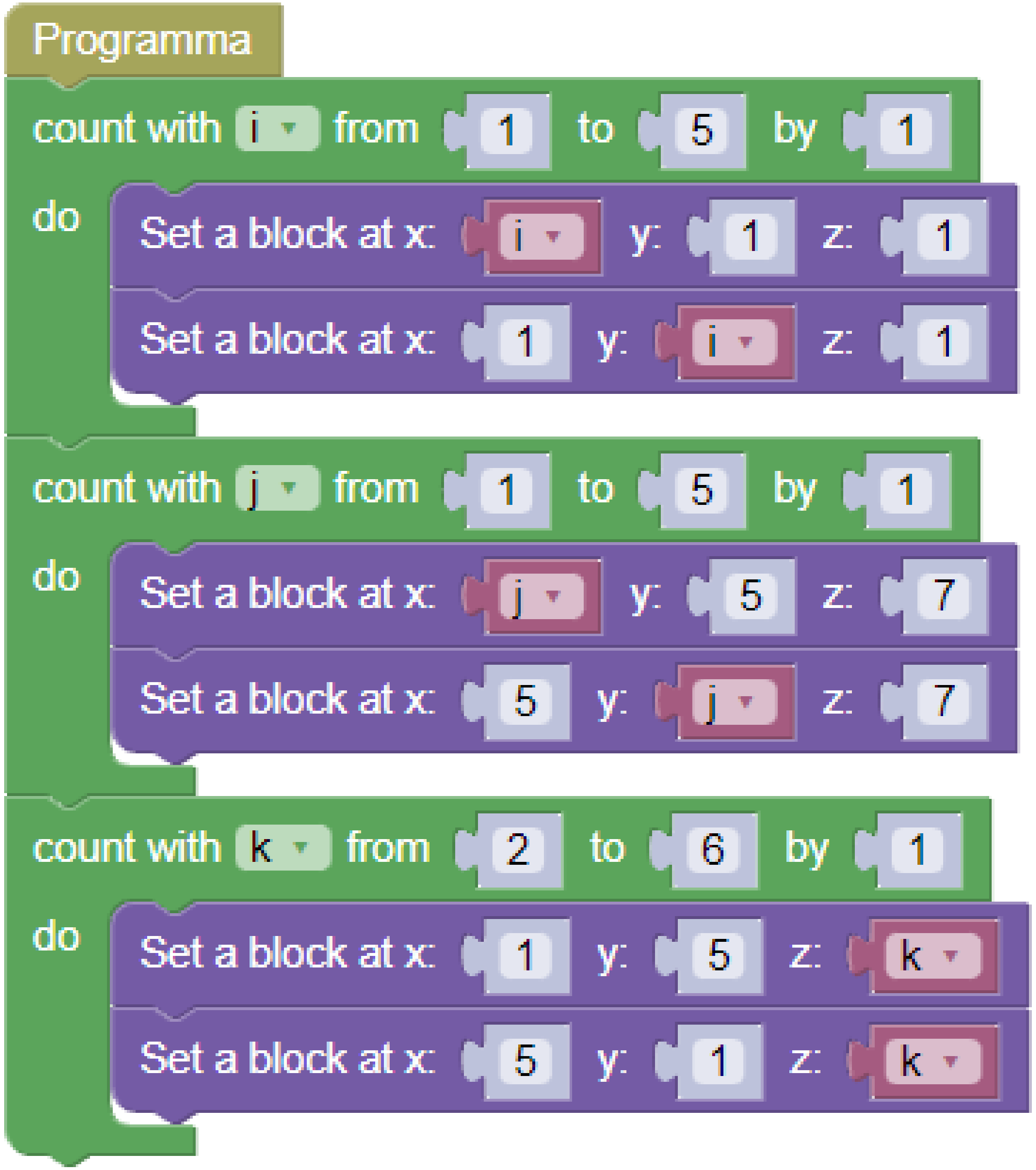
Task 3



Task 3

combine repeat blocks

Task 3


Programma
count with i from 1 to 5 by 1
do
Set a block at x: i y: 1 z: 1
Set a block at x: 1 y: i z: 1
count with j from 1 to 5 by 1
do
Set a block at x: j y: 5 z: 7
Set a block at x: 5 y: j z: 7
count with k from 2 to 6 by 1
do
Set a block at x: 1 y: 5 z: k
Set a block at x: 5 y: 1 z: k

Design a (series of) task(s)

Design a (series of) task(s) to develop CT skills.
Pay attention to the following:

- What learning goals do you aim at?
- What target group?
- What CT aspect(s)?

Discussion

- What CT aspects do you see in these tasks?
- What CT aspects do you think are especially challenging for your students?
- How to design a series of these tasks to develop CT skills?
- What is the added-value of AR?
- What issues might teachers encounter?
- How can teachers be supported?
- …

Alternative CT task: Numworx DME – Programming cubes

https://app.dwo.nl/en/se/?locale=en&hash=#s:581821

[redacted]

Thank you!

Please feel free to contact me, if you have questions.

Sylvia van Borkulo, s.vanborkulo@uu.nl