CHILDHOOD MYOPIA AND LIGHT EXPOSURE IN SCHOOL ENVIRONMENTS

SABINE DE GROOT
4555864

Main mentor: Eleonora Brembilla
Second mentor: Michela Turrin

CONTENTS

1. BACKGROUND

Background literature - What is myopia?

Problem statement

Research question

Background literature - Potential design adaptations

2. METHODOLOGY

Measurements

Simulations

Case studies

3. RESULTS

Measurement results   - DS Abraham Hellenbroekschool

                                                 - Pniëlschool

Calibration 3D-model   - Photopic illuminance

                                                 - Cumulative illuminance

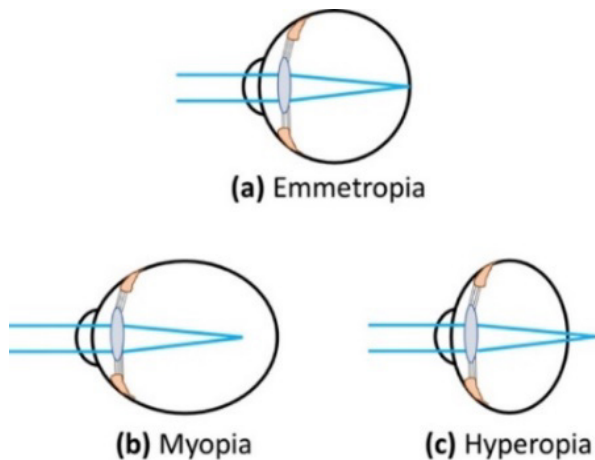   - Melanopic illuminance
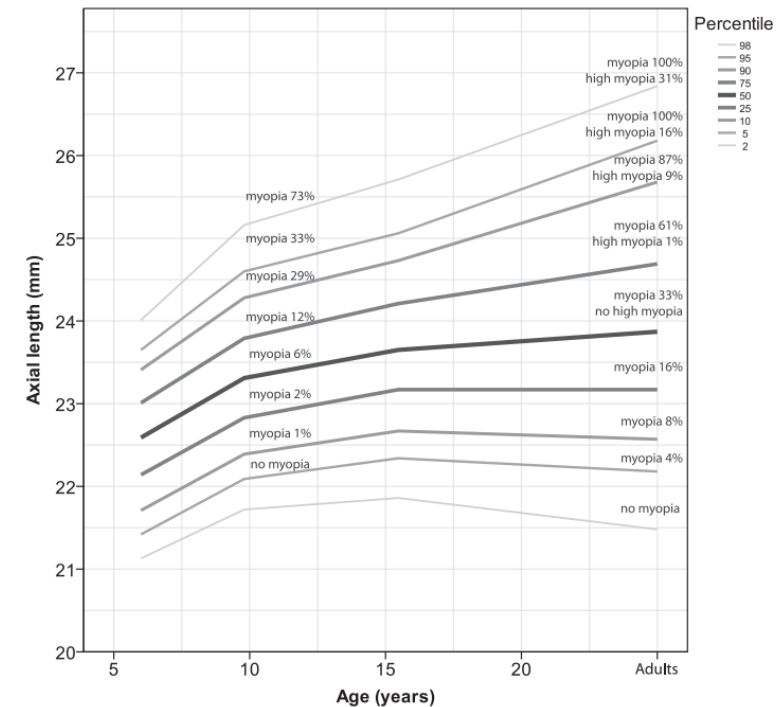
Design adaptations

Design matrix

4. DISCUSSION & CONCLUSION

BACKGROUND

1.

BACKGROUND LITERATURE
WHAT IS MYOPIA?

- Eye disorder in which the eyeball grows longer what causes bad eyesight

- Also known as nearsightedness

- Onset at young age

- Differences in ethnicity

(a) Emmetropia

(b) Myopia

(c) Hyperopia

(Carr & Stell, n.d.)

(Tideman, Polling, Vingerling, Jaddoe, Williams, Guggenheim & Klaver, 2018)

PROBLEM STATEMENT

- In recent years, a bigger part of population has developed myopia

- If nothing is done, 50% of world population will have myopia by 2050

- Can lead to serious eye disorders and blindness

28%
of the world's population suffered from myopia in 2010, equal to 1.95 billion people
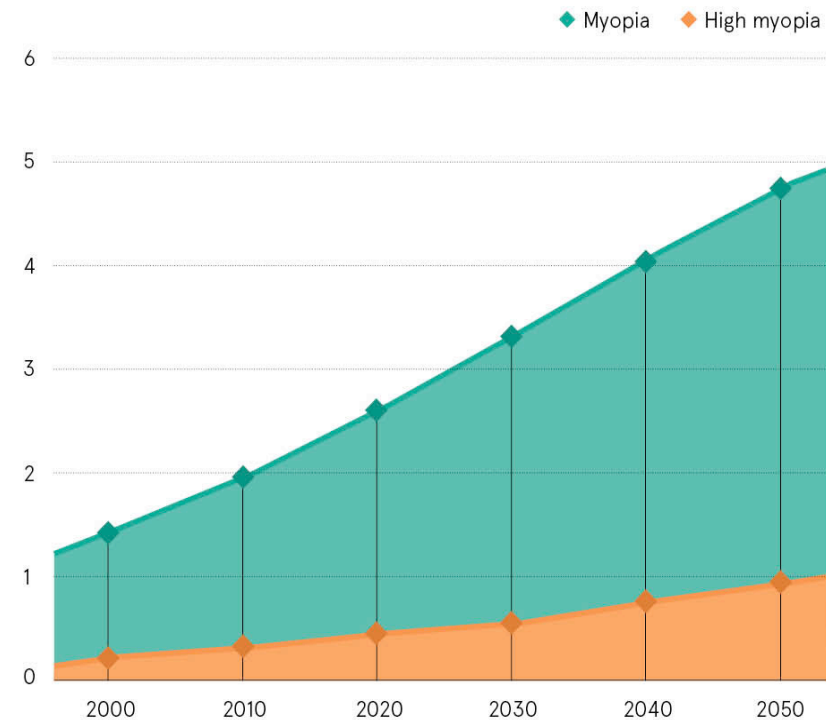
938m
people are predicted to suffer from high myopia by 2050, which puts them at risk of more serious eye conditions

50%
are expected to by myopic by 2050, equal to 4.76 billion people

Growing prevalence of myopia worldwide
Number of people (bn)

◆ Myopia   ◆ High myopia

Cao Thang Eye Hospital, 2018

RESEARCH QUESTION

HOW CAN SCHOOL BUILDING DESIGN HELP TO REDUCE CHILDHOOD MYOPIA?

- 1. What is myopia and what causes it?

Literature review

- 2. How can myopia development be reduced in relation to architecture?

Literature review

- 3. What is the current situation of a recently built and a renovated school building?

Measurements

- 4. What can be improved in a recently built and a renovated school building?

Simulations

- 5. What design choices in school buildings can be made to decrease myopia?

Design matrix

BACKGROUND LITERATURE
POTENTIAL DESIGN SOLUTIONS

- Upcoming topic
- Relationship between light on eyeball and development of myopia
- The more light, the better for reducing myopia
- Training the eye by watching further into the distance more often is also important

DESIGN TOOLS

- Green outdoor space
- Visual colour spectrum
- Non-visual light
- Materials and interior

METHODOLOGY

2.

METHODOLOGY

MEASUREMENTS

- Illuminance: the amount of lux on eyelevel in different positions

  The higher the lux level, the better for reducing myopia

- The amount of lux over a longer timeframe with hobo loggers

  Can be compared with the data available from the weather station

- Indoor spectral power distribution with the illuminance spectrophotometer

  Ends of colour spectrum wavelengths (red and blue) can help to reduce myopia & to calculate the melanopic illuminance

- Reflectance of materials

  To insert in the 3D model for the simulations

SIMULATIONS

- 3D model in Rhino + script in Honeybee & Lark (Grasshopper) to:
  - Validate the measurement results
  - Test design adaptations
- Rate design adaptations in design matrix
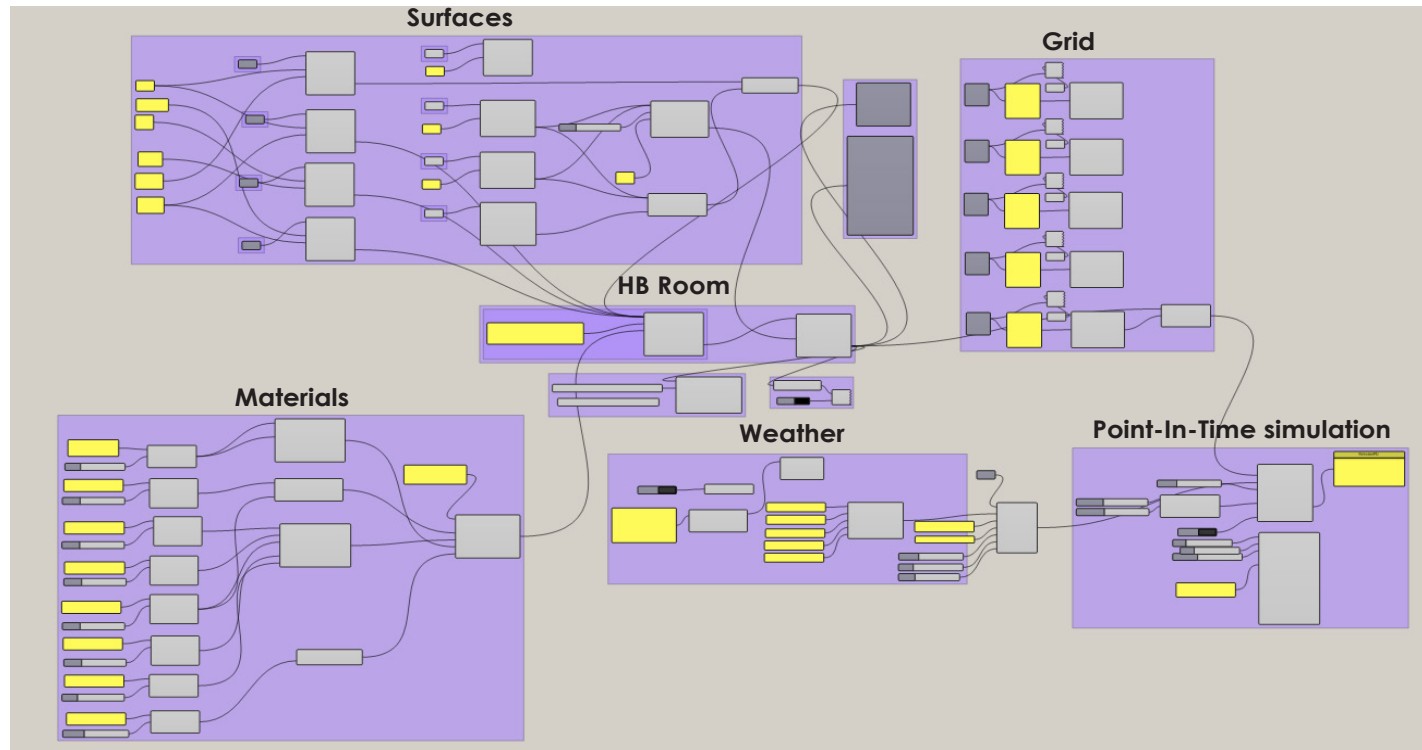
RESULTS

3.

MEASUREMENT RESULTS
CASE STUDIES

DS ABRAHAM HELLENBROEKSCHOOL
ZWIJNDRECHT
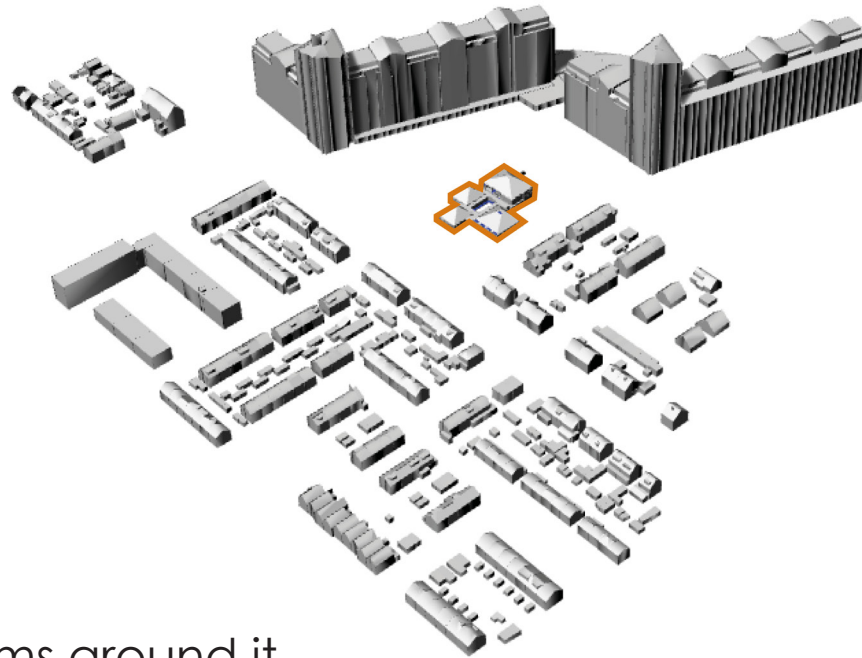
- Built in 2022
- Courtyard with classrooms around it
- Big playground around it
- High-rise on the north
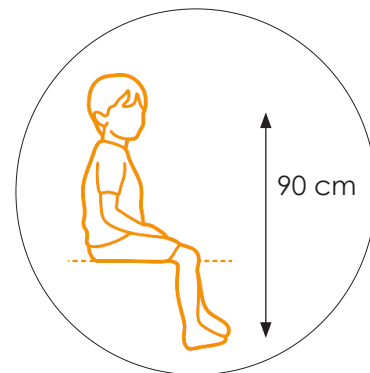
12
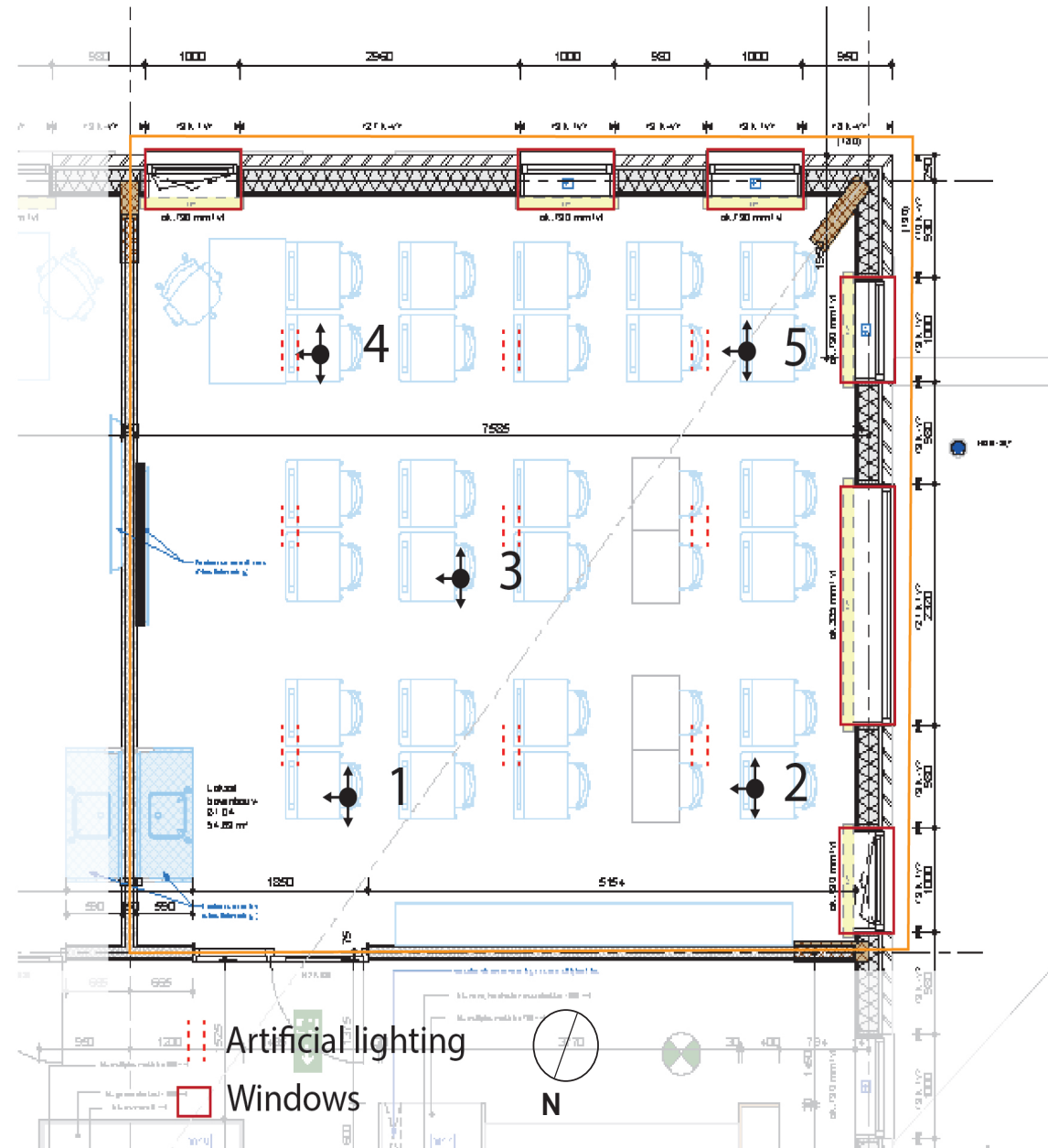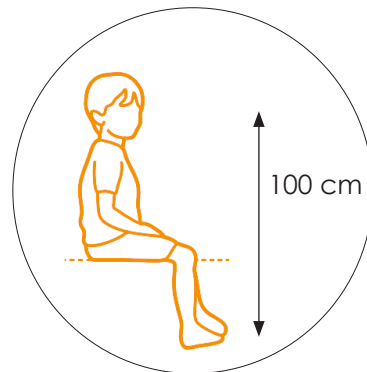
MEASUREMENT RESULTS
HELLENBROEKSCHOOL
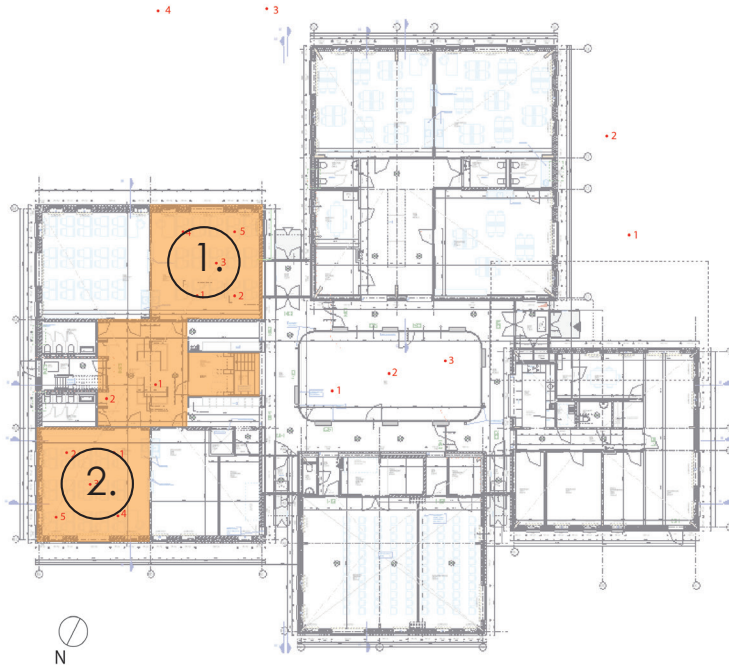
Ground Floor
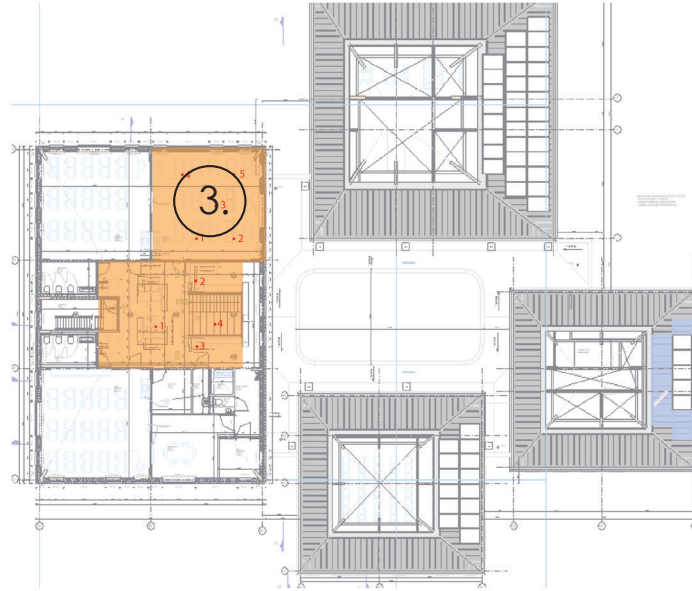
First Floor

- blinds 0%, artificial lighting 0%
- blinds 0%, artificial lighting 100%
- blinds 50%, artificial lighting 0%
- blinds 100%, artificial lighting 0%
- blinds 50%, artificial lighting 100%
- blinds 100%, artificial lighting 100%
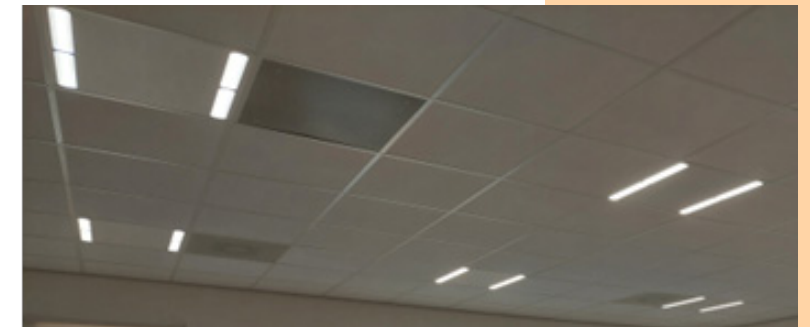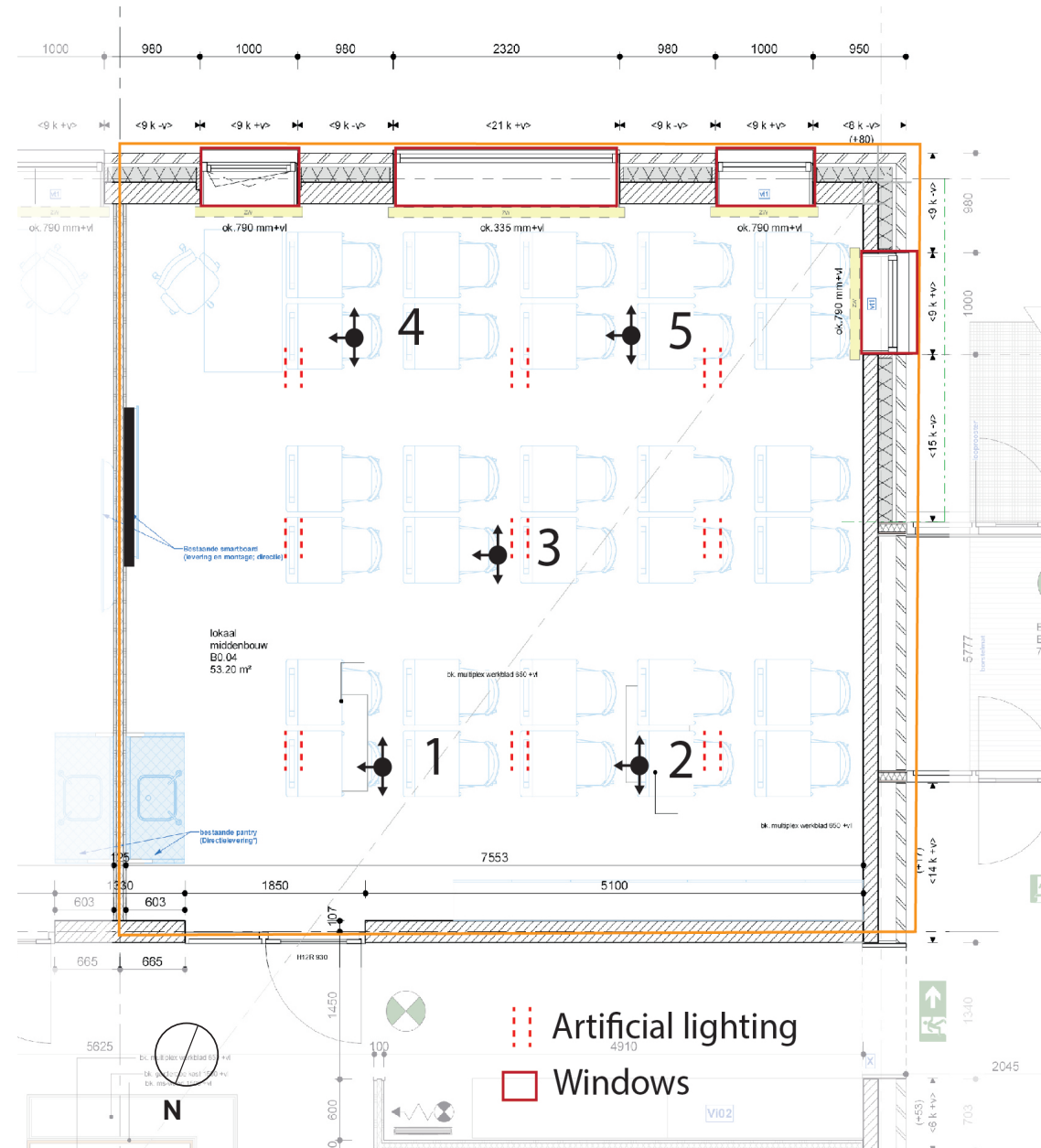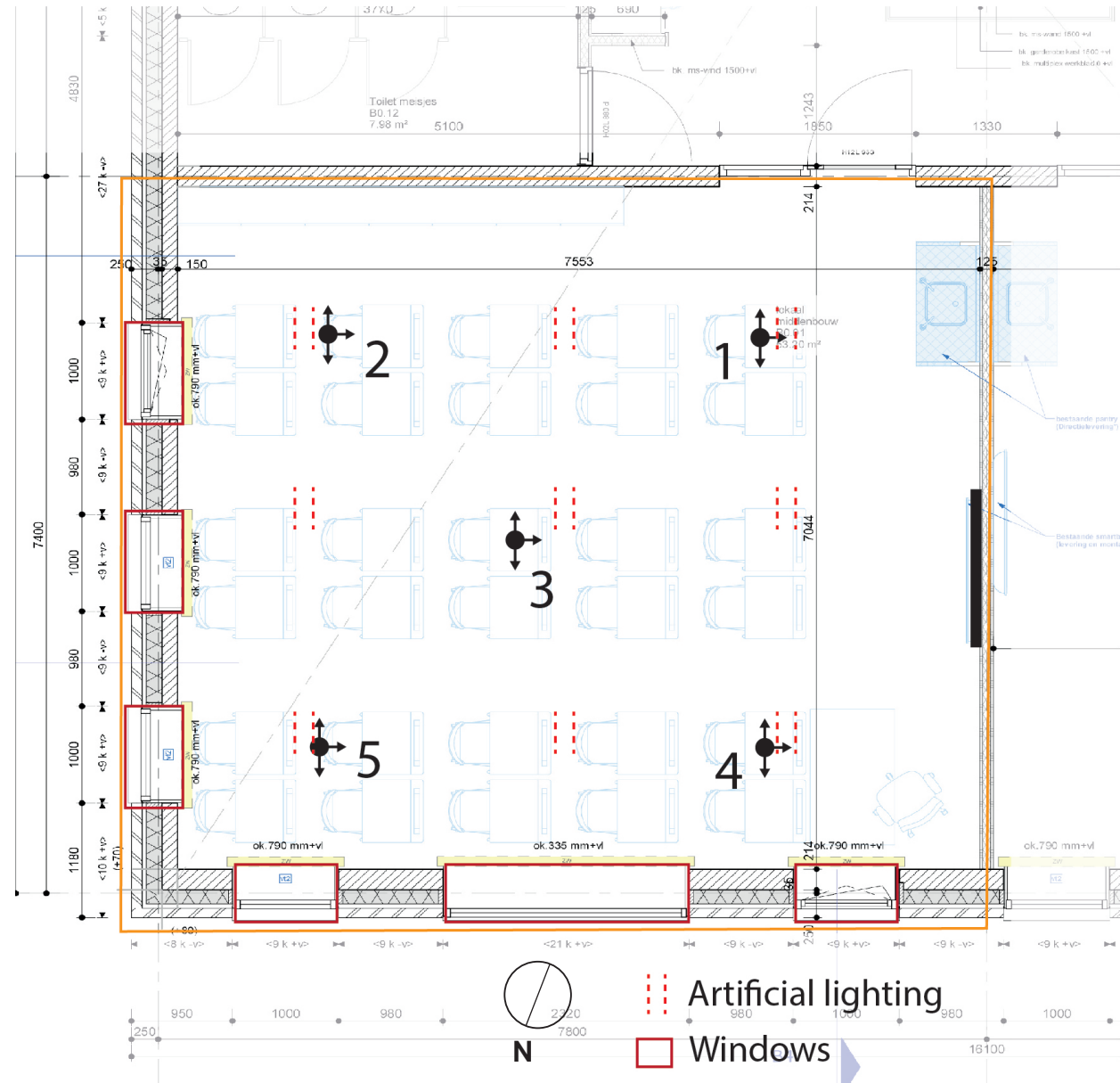
13

MEASUREMENT RESULTS
HELLENBROEKSCHOOL
CLASSROOM 1

90 cm

Artificial lighting

Windows

MEASUREMENT RESULTS
HELLENBROEKSCHOOL CLASSROOM 2

100 cm

N

⋮ Artificial lighting

▢ Windows

HELLENBROEKSCHOOL
CLASSROOM 3

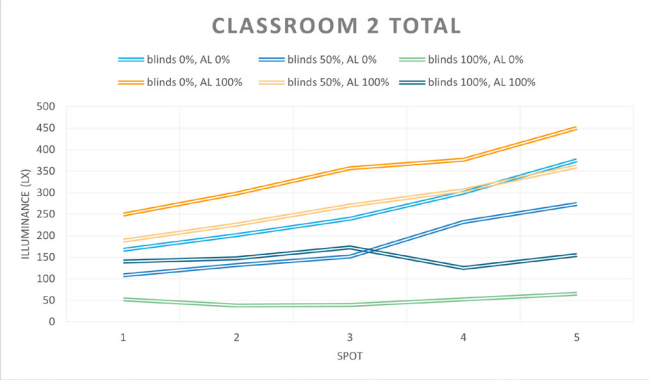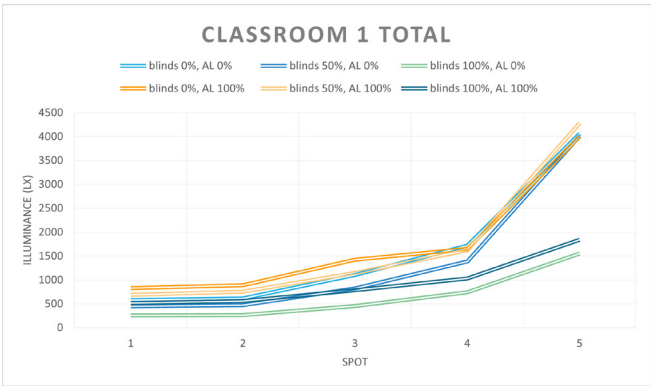100 cm

Artificial lighting

Windows

N

MEASUREMENT RESULTS
HELLENBROEKSCHOOL

2nd of March
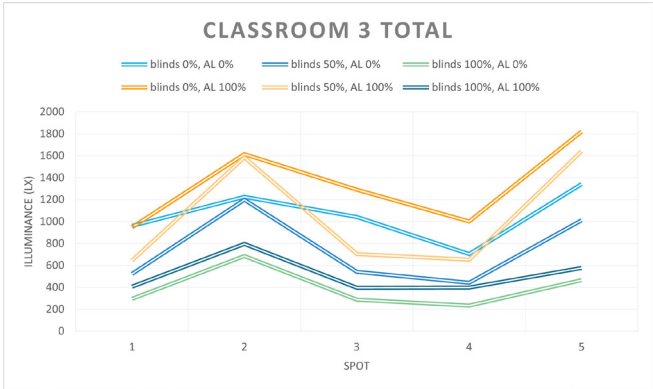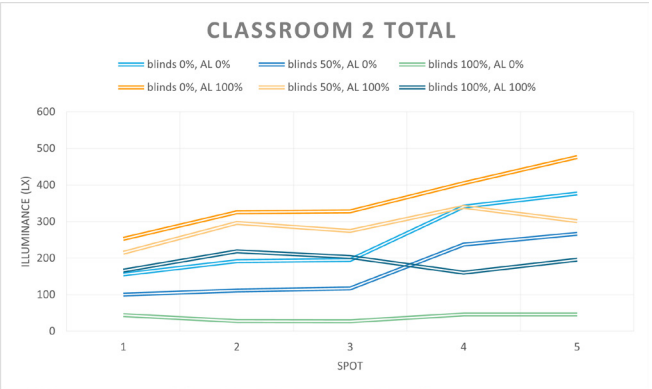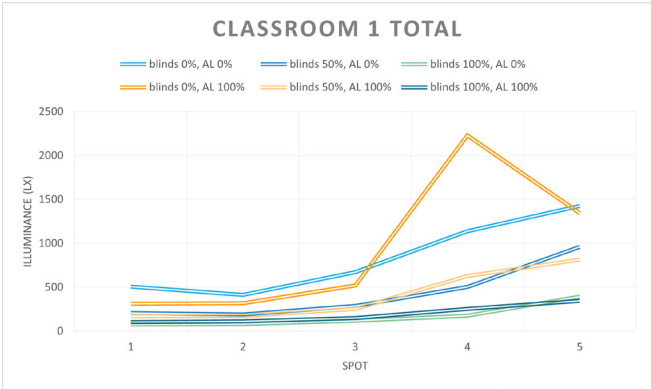
3rd of May
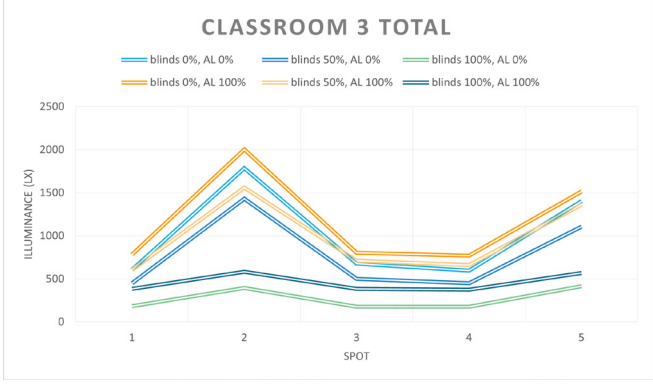
MEASUREMENT RESULTS
CASE STUDIES

PNIELSCHOOL
ROTTERDAM

- Built in 1920, renovated in 2022
- More windows to get more light inside
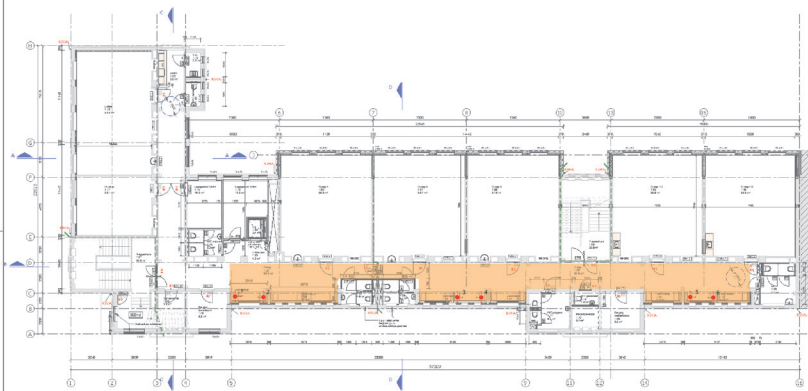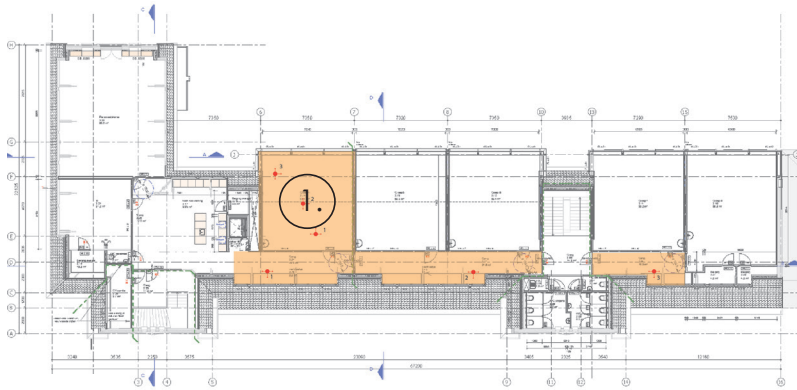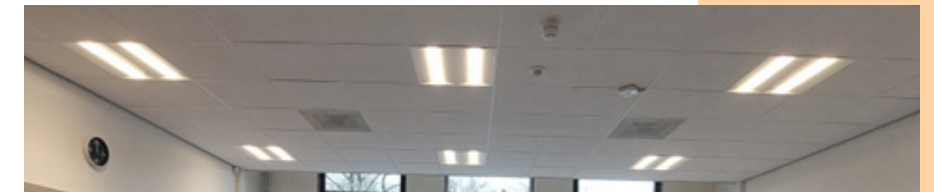- Same height buildings around it
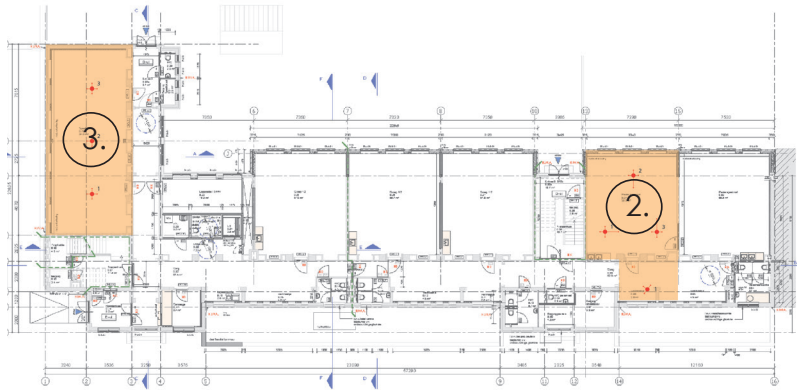
PNIELSCHOOL

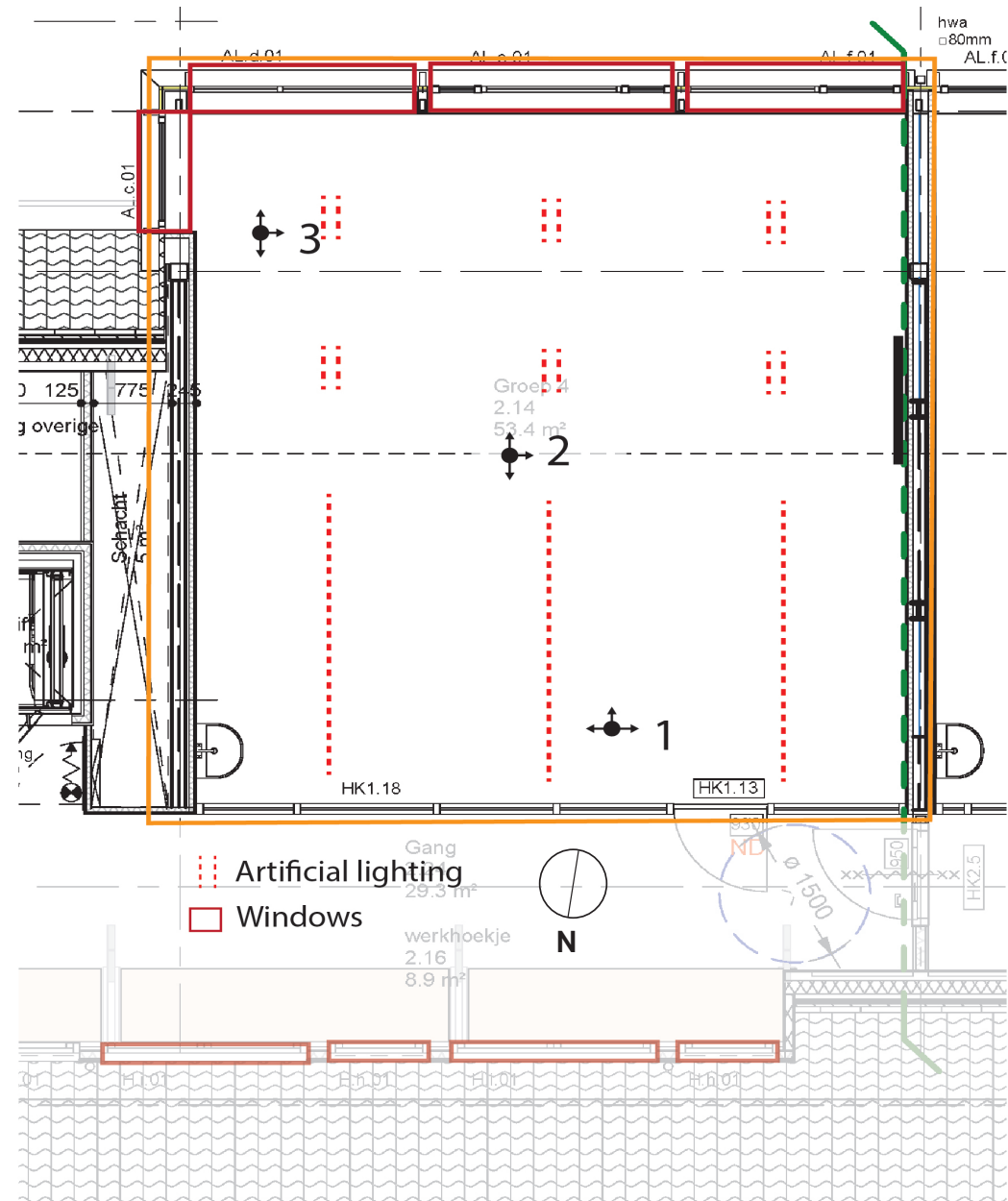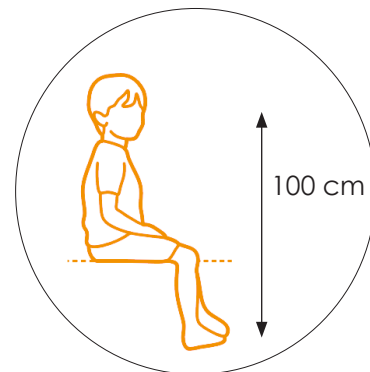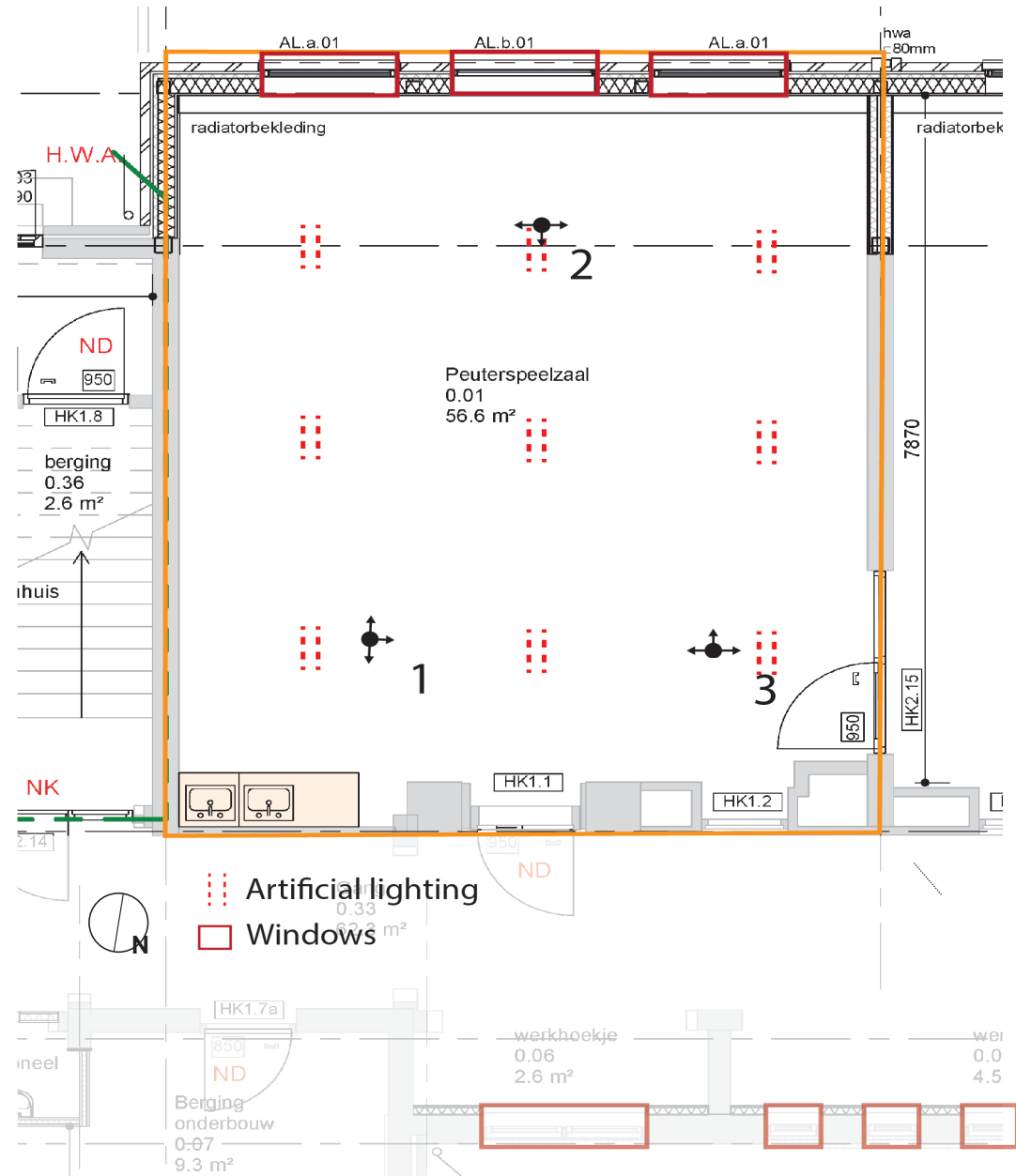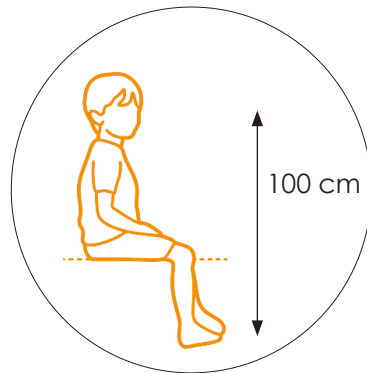Ground Floor

First Floor

Second Floor

N

- blinds 0%, artificial lighting 0%
- blinds 0%, artificial lighting 100%
- blinds 100%, artificial lighting 0%
- blinds 100%, artificial lighting 100%

Artificial lighting

Windows

100 cm

N

PNIELSCHOOL
CLASSROOM 2

100 cm

Artificial lighting
Windows

Peuterspeelzaal
0.01
56.6 m²

radiatorbekleding
radiatorbek

H.W.A

ND
950
HK1.8

berging
0.36
2.6 m²

huis

NK

AL.a.01   AL.b.01   AL.a.01

hwa
80mm

7870

HK2.15
950

HK1.1
HK1.2

ND

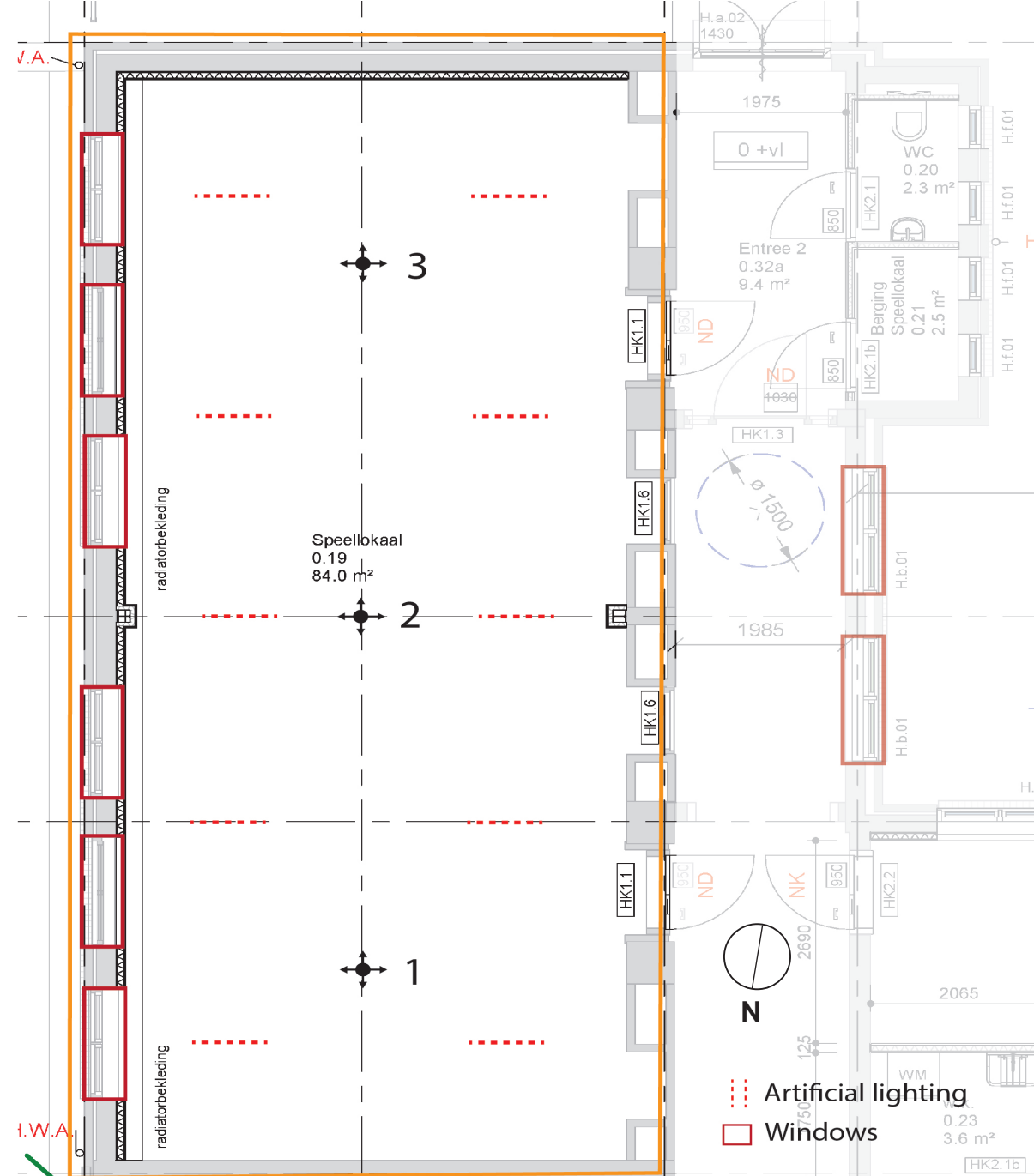N

HK1.7a
850
ND

Berging
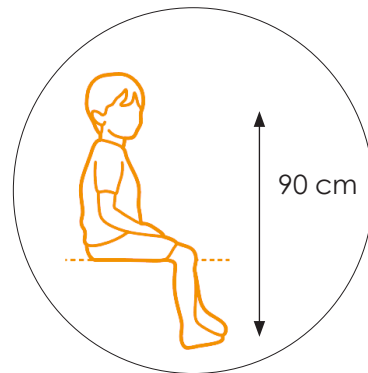onderbouw
0.07
9.3 m²

werkhoekje
0.06
2.6 m²

wer
0.0
4.5

0.33
m²

MEASUREMENT RESULTS
PNIELSCHOOL
CLASSROOM 3

90 cm

Speellokaal
0.19
84.0 m²

3

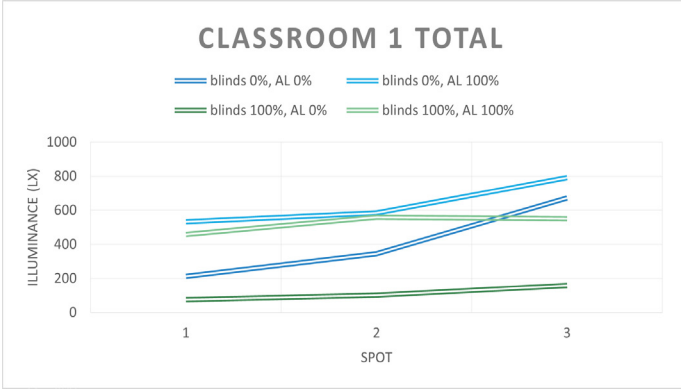2

1

Artificial lighting

Windows

N

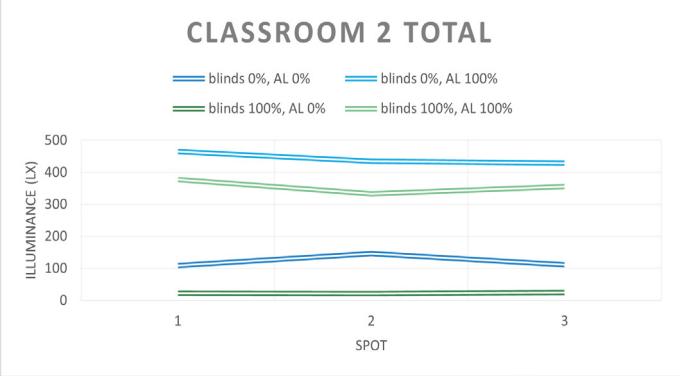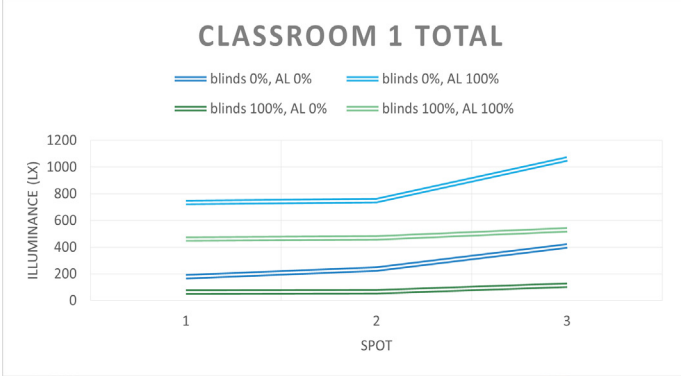# MEASUREMENT RESULTS
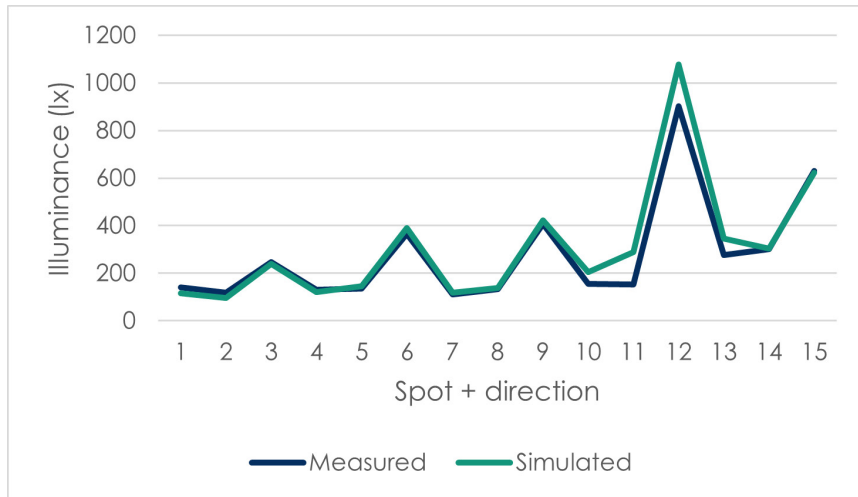## PNIELSCHOOL

7th of March
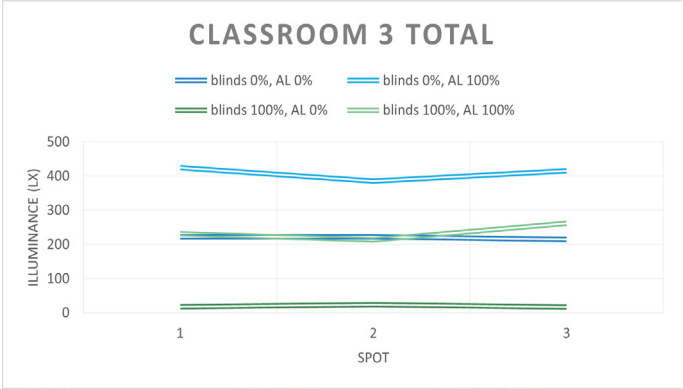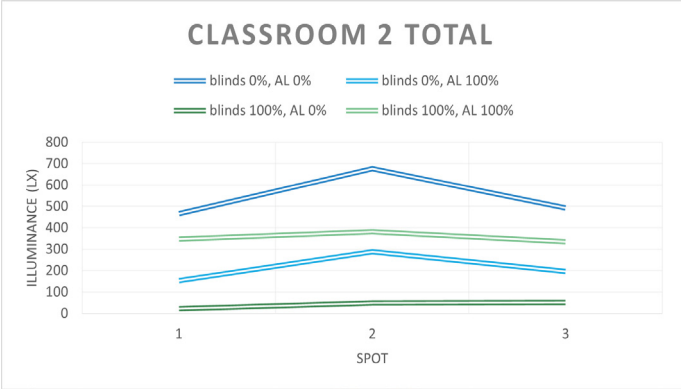
15th of May
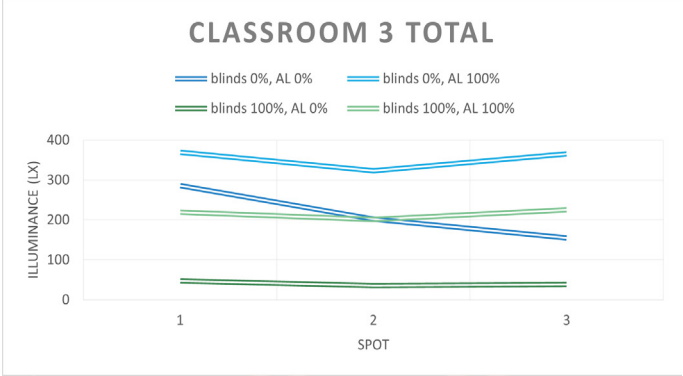
CALIBRATION 3D-MODELS
PHOTOPIC ILLUMINANCE

- Calibration 3D model to see how well it represens the reality

Hellenbroekschool - classroom 2
March 2nd

blinds 0%, AL 0%

nMBE   **16,3%**

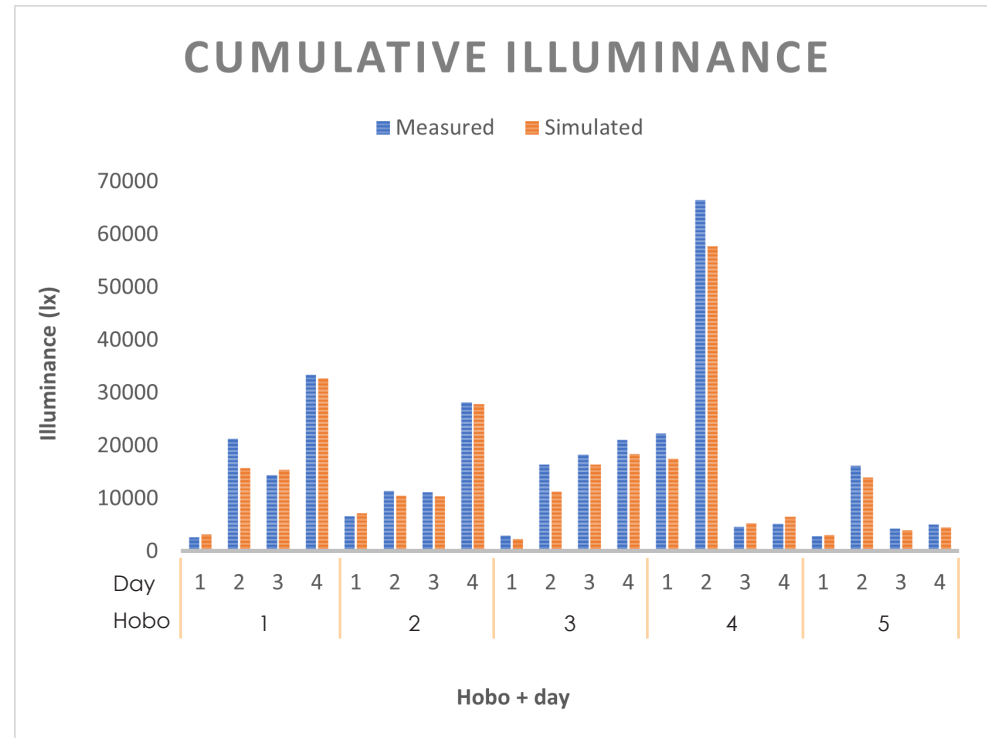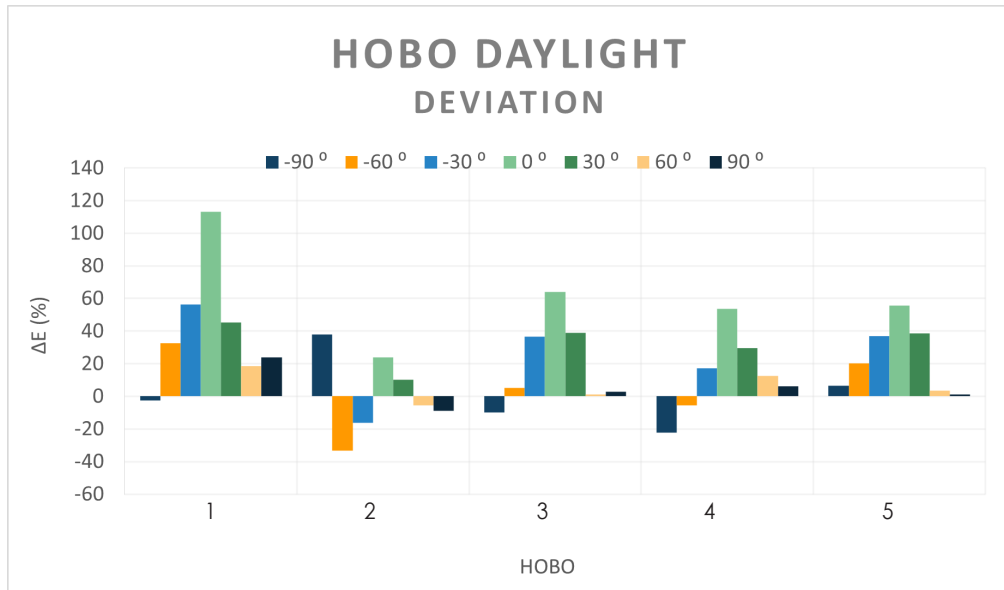**Pniëlschool - classroom 2**
May 15th

blinds 0%, AL 0%

nMBE   **109,8%**

CALIBRATION 3D-MODELS
CUMULATIVE ILLUMINANCE

- Hobo loggers are typically characterised by larger errors than research-grade illuminance meters.

- Point-In-Time simulations for every hour on school for best and worst day

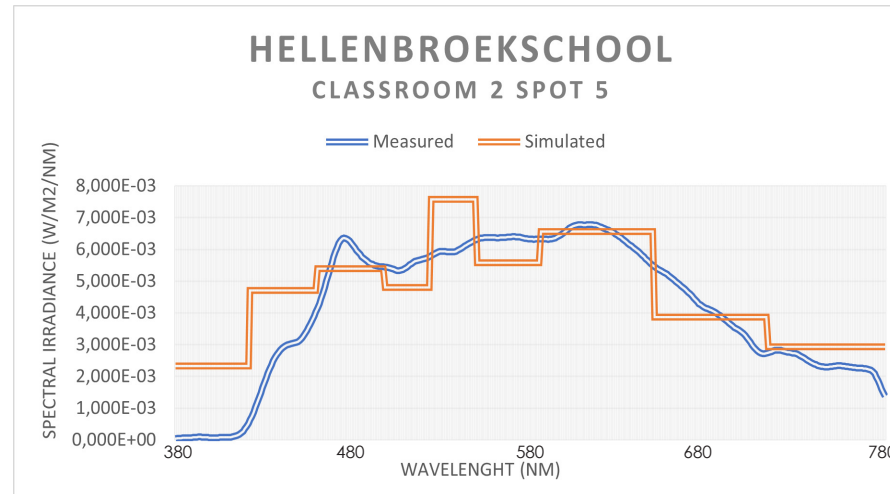- Simulated values slightly underestimated (-5,6%) on average
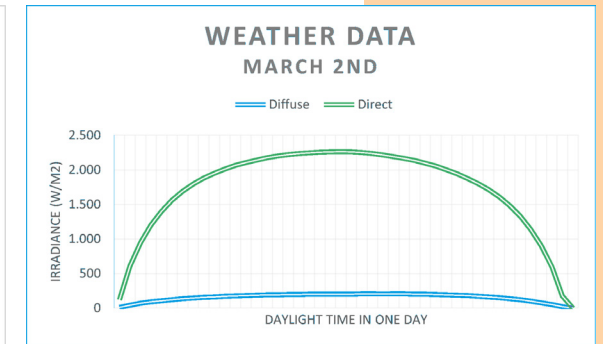
CALIBRATION 3D-MODELS
MELANOPIC ILLUMINANCE

- Spectral irradiance: measured vs simulated

- Best and worst case are on the same spot in the same class room, but on another day

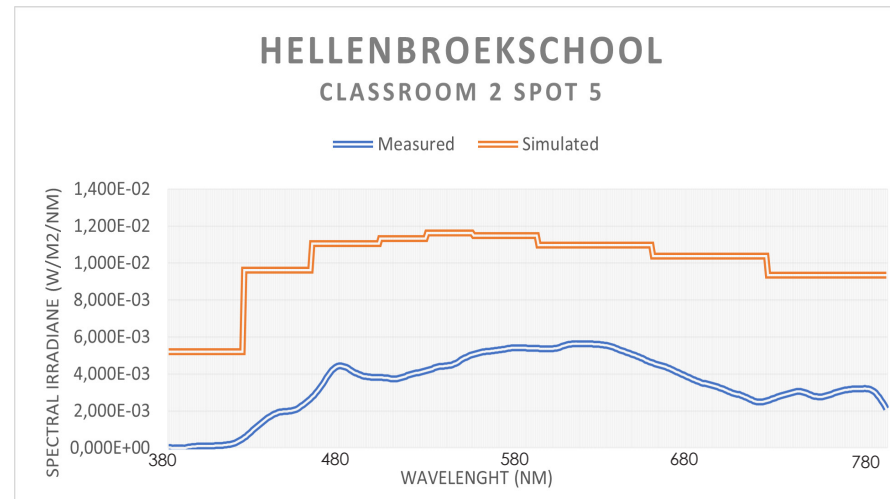- With a clear sky the model represents the reality better

2nd of March, blinds 0% AL 100%

31,2%

3rd of May, blinds 0% AL 100%
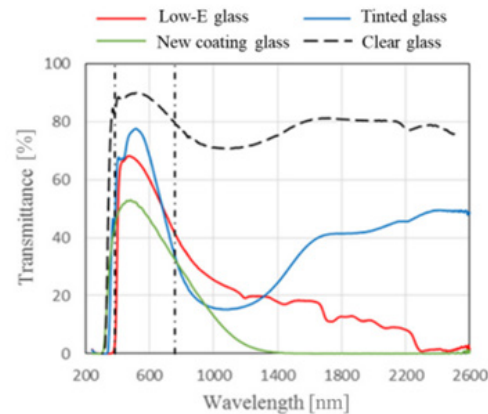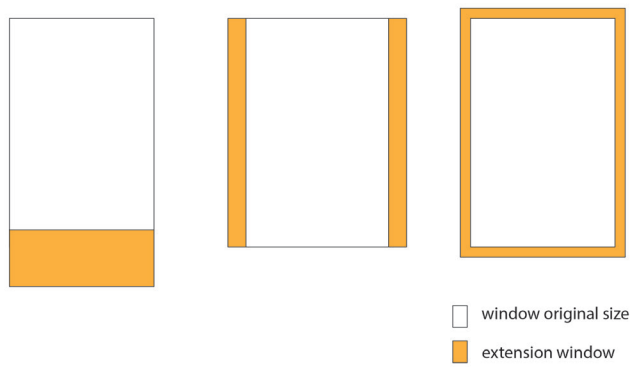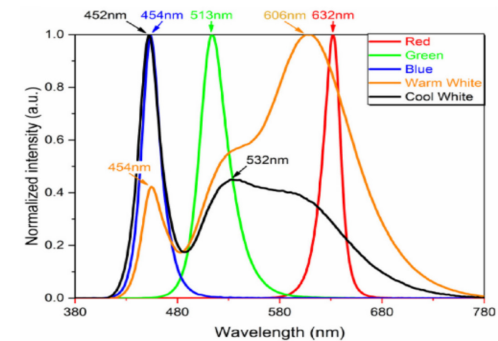

187,1%

26
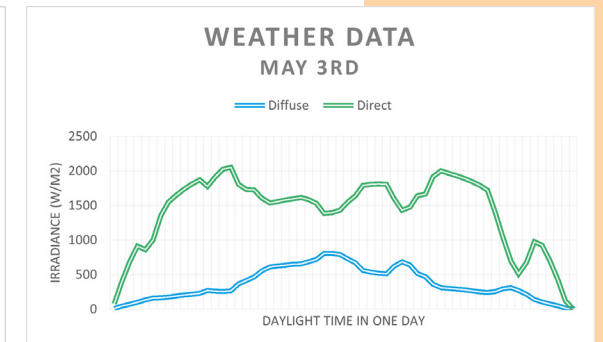
DESIGN ADAPTATIONS

- Making the windows 25% bigger (lower, wider and overall)
- Changing the colour of the interior walls
- Changing the material of the ceiling
- Changing the material of the floor
- Changing the glazing type
- Replacing sun shading

window original size

extension window

(Wang & Zhang, 2019)

(Baeza Moyano & González-Lezcano, 2021)

SIMULATION RESULTS - PHOTOPIC ILLUMINANCE

MOST EFFECTIVE

- Enlarging windows: wider
- Light-coloured floor
- White painted ceiling
- White thin sun shading

Legend:
- ☐ Simulated
- ☐ Windows 25% bigger - lower
- ☐ Windows 25% bigger - wider
- ☐ Windows 25% bigger - overall
- ☐ Red interior walls
- ☐ Blue interior walls
- ☐ Yellow interior walls
- ☐ Light wooden floor
- ☐ White painted ceiling
- ☐ Low E glass

28
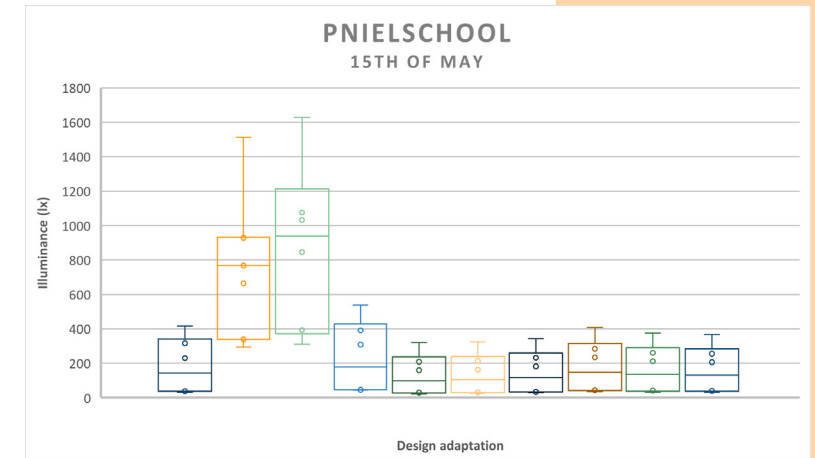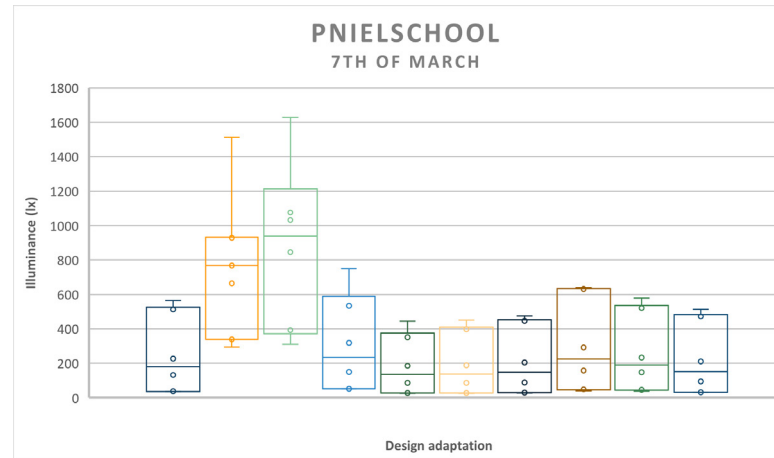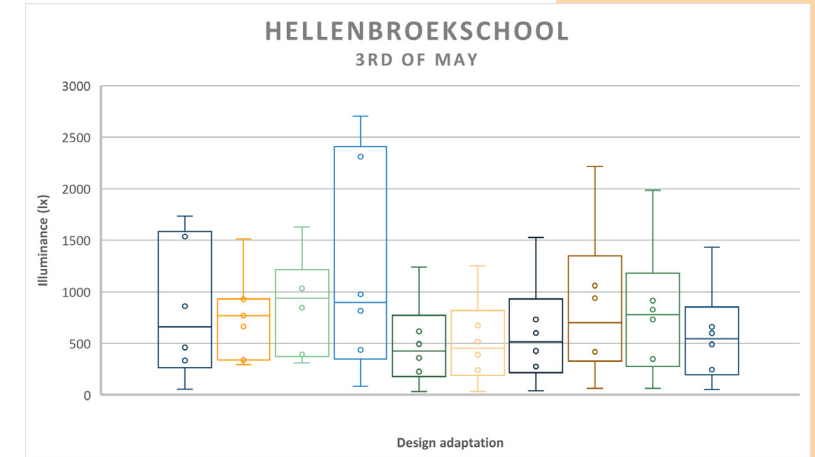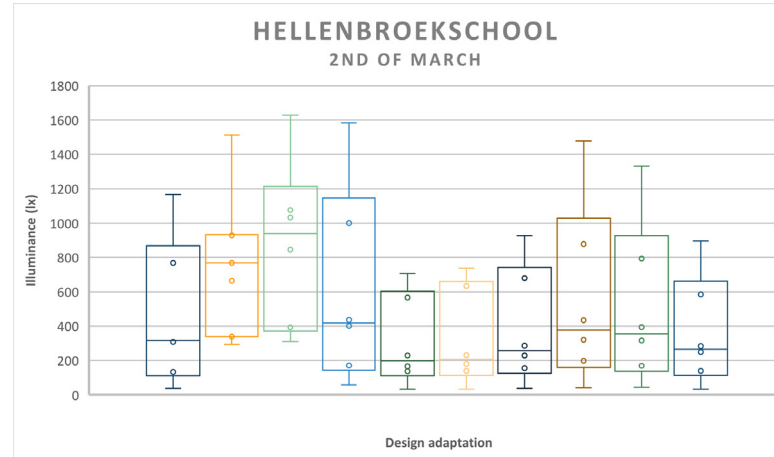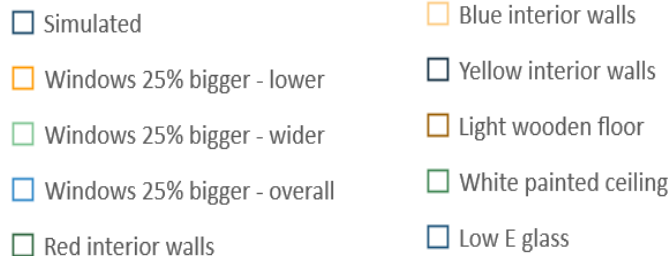
DESIGN MATRIX
RENOVATION

- Rated on effectivity, feasibility and costs
- Enlarging the windows not recommended
- Painting the walls not recommended
- Low-E glass not recommended
- Light-coloured floor, white ceiling
  and white thin sun shading best design
  options

Design adaptation	Effect	Feasibility	Costs	Total
Windows 25% bigger – lower	+	– – –	– – –	– –
Windows 25% bigger - wider	+ +	– – – –	– – – –	– –
Windows 25% bigger – over all	+	– – – – –	– – – – –	– – – –
Red interior walls	– –	+ +	+	–
Blue interior walls	– –	+ +	+	–
Yellow interior walls	–	+ +	+	+ –
Light wooden floor	+ +	+	+ –	+ +
White painted ceiling	+	– –	–	+
Low E glass	–	–	– –	– –
White thin sun shading	+ +	–	+ –	+ +

DESIGN MATRIX
NEW SCHOOL BUILDINGS

- Rated on effectivity, feasibility and costs
- Windows wider is recommended
- Easier to change

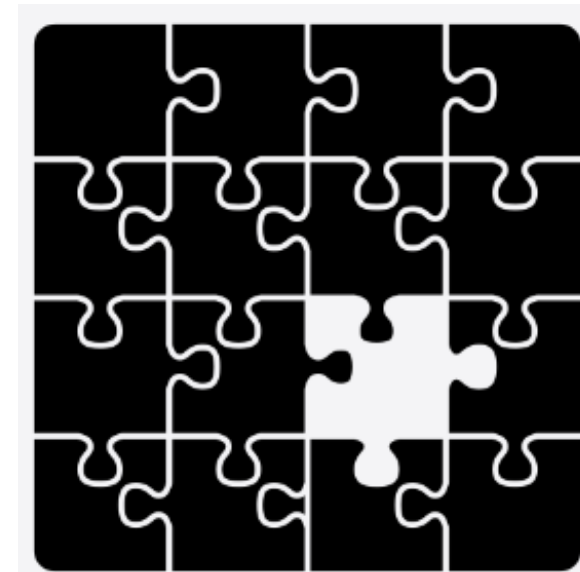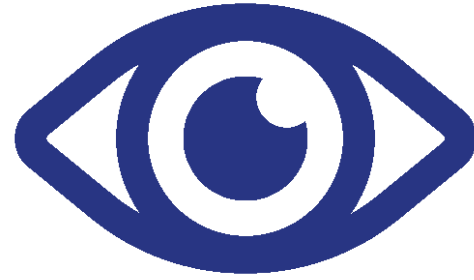| Design adaptation	Effect	Feasibility	Costs	Total
Windows 25% bigger – lower	+	+ −	+ −	+
Windows 25% bigger - wider	+ +	+ −	+ −	+ +
Windows 25% bigger – over all	+	+ −	+ −	+
Red interior walls	− −	+ +	+	−
Blue interior walls	− −	+ +	+	−
Yellow interior walls	−	+ +	+	−
Light wooden floor	+ +	+ +	+	+ +
White painted ceiling	+	−	−	+ +
Low E glass	−	+ +	−	−
White thin sun shading	+ +	+ −	+	+ +

DISCUSSION & CONCLUSION

4.

DISCUSSION & CONCLUSION

- Several design adaptations can improve illuminance levels inside

- Sitting positions and directions can have significant differences

- However, it is not known how much this helps for reducing myopia development

- Further research needed

- This research as a start of an important topic

THANK YOU