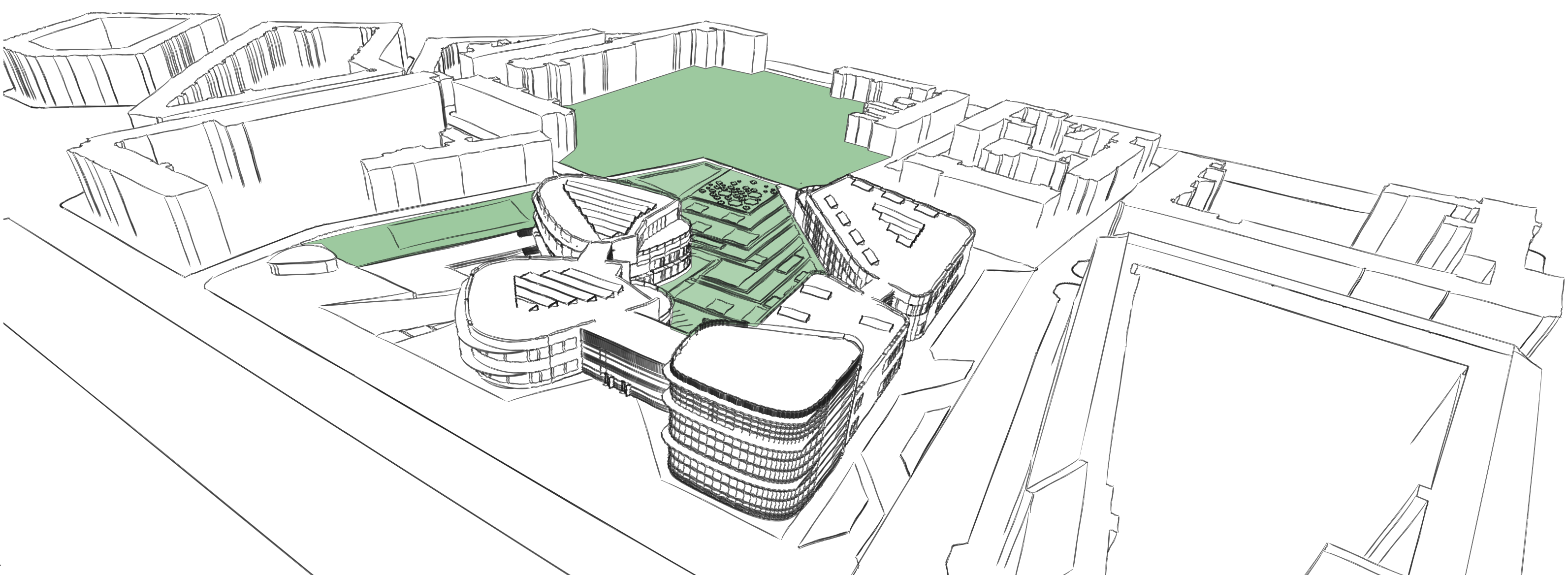
T H E   G A R D E N   S C H O O L in the dense city of Aarhus



ma4-ark39 2011

Department of Architecture, Design and Media Technology, Aalborg University

Dovile Puraite, Ausrine Bredulyte & Tina Bredgaard

SYNOPSIS

This project deals with the task of designing a new public school in the district of Frederiksbjerg, Aarhus. The new school will replace the current school of N.J Fjordsgade which no longer fits the growing number of pupils and changing educational needs.

The architectonical expression states firmly that the new design is a place for children. Playful facades, softly curved walls as well as a variety of outdoor activities and greenery make the new school a children friendly area that appeals to a synergy of play, learning and movement.

Based on good daylight conditions, comfortable temperatures and healthy ventilation strategies a healthy indoor climate is integrated into the design to ensure effective learning conditions for the children.

Not only the pupils and teachers benefit from the new school, so do the residents of the area as well. Some of the functions, such as a skatepark, a canteen/cafe or a sports center, can be used by the residents and guests of Frederiksbjerg,

TITLE PAGE

This master thesis has been completed at the civil engineering education at Architecture & Design, Aalborg University.

MAIN THEME:	Elementary school
PROJECT TITLE:	››The Garden School in the dense city of Aarhus‹‹
PROJECT GROUP:	Dovile Puraite, Ausrine Bredulyte and Tina Bredgaard, ma4-ark39 Department of Architecture, Design and Media Technology, Aalborg University
PROJECT PERIOD:	01.02.2011-31.05.2011
REPORT PRINT:	6
PAGES:	176
MAIN SUPERVISOR:	Peter Mandal Teaching Associate Professor, Department 19, Aalborg University
TECHNICAL SUPERVISOR:	Anna J. Marszal PhD Fellow, Department 19, Aalborg University

Dovile Puraite Ausrine Bredulyte Tina Bredgaard

THANKS

We wish to thank the people who have contributed to this project with information, expertise and inspiration:

Project Manager for RULL (Rum til Leg og Læring) and caseworker:
Lene Vestervang Olsen

Head of Secretariat at the School of N. J. Fjordsgade:
Susanne Landergren Due

Teacher at the School of N. J. Fjordsgade:
Vibeke Wiwe

Associate Professor at Egå Gymnasium:
Kristian Thisted Nielsen

SFO director at the School of Lisbjerg:
Ejnar Dahl-hansen

Headteacher at Lisbjerg School:
Lars Wørtz

Architect:
Jørgen Funck

Ill. 1.1 Children playing

READING GUIDE

REPORT

This project has been prepared as part of the project process on 4. MSc. AD of Institute of Architecture & Design at Aalborg University. The project was prepared during the period of 1st February 2011 to 31st May 2011.

Although the design process has been iterative, the report presents the phases in a thematical chronology, so to speak. The report begins with a presentation of the final project proposal. This is to give the reader an early idea of what the final design looks like, in order to better understand the thoughts and ideas of the design process. The base of the project is described in a program, while the iterative design process is described in a sketching and synthesis phase that ends with a reflection of the project and an appendix.

CD

The attached CD contains:

- Be10
- VE - Virtual Environment
- Air change calculations
- Literature
- The final report

REFERENCES

References are used in accordance to the Harvard Method [author year] for books and articles, [“title” year] for reports and [designated name] for internet websites. These refer to the full list of references found at the end of the report.

References for illustrations are indicated by continuous numbers through the report [ill. #] and refers to the illustration list found at the end of the report. References for appendixes are indicated [Appendix #]

TABLE OF CONTENT

INTRODUCTION

It has for several years been a stated objective for Denmark to have the world's best public schools. But the pedagogical principles and the requirements for learning environments change over time. We gain more insight about what works and what does not work, and at the same time the society changes and place new demands on the ballast needed to prepare our children for the further education system as well as to the changing labor market. Several public schools around the country, are faced with big challenges in adapting the existing school buildings to contemporary pedagogy. Many of them are built in a time where the focus was on things other than flexibility, independence and well-being, as are some of the prominent educational principles of today.

Consensus to make an effort

The Government's Quality Fund (Kvalitetsfonden) has allocated 22 billion kroner for improvements to day care centers, schools, sports facilities and the elderly until 2018. The money comes on top of the 6 billion kroner that the country's municipalities has planned to invest in renovations, conversions and new construction of schools in 2011 and 2012. So there is consensus to make an effort to create the physical framework that can support the new educational principles and meet the requirements of our education system. However, there is no clear recipe for how to do it. Many of the country's municipalities have embarked on the attempt to make "the good public school". It is still too early to conclude who has found the right formula, if any, but there are a number of good cases from which this project has found inspiration. Thus this project's intention is to participate in the debate on what physical framework is required for "the good public school".

This project

The city council of Aarhus municipality has decided that over a period of ten years starting from 2009, 1.3 billion kroner will be allocated for the improvement of educational and technical indoor and outdoor environments of schools and leisure activities in the municipality.

In May 2009, the parties of the city council agreed on a new city school in the school district of N.J. Fjordsgade. The new school project is intended to create a coherent children and adolescent environment on the site where the School of St. Annagade and the School of Kroghsgade is located today. The new public school will replace the current School of N.J. Fjordsgade, which has 745 pupils attending. The current School of N.J. Fjordsgade no longer has the

required space to accommodate the growing number of students, and also there is a great need for modernization. A new building is necessary since a modernization of the current building will not be able to meet the high demands of tomorrow's primary school in N.J. Fjordsgade's school district.

An open assignment

Aarhus Municipality has drafted a vision for the project in a consultation draft (høringsudkast), but there is not yet a room program for the School of N.J. Fjordsgade, just as there is no municipality plan for the area. What however is certain is that the school buildings should be about 12,750 square meters and accommodate 850 pupils from 0-9th grade, incl. SFO.

The competition paper is only in its fledgling stage, and thus it is a very open assignment. That of course offers great challenges but it also provides for more free opportunities in designing, and that has been one of the reasons for the choice of project. The school will be located in an interesting, very lively district in the city center of Aarhus, and much of the challenge is to identify values in the area and integrate "the good public school" into the city functions.

Problem

Based on Aarhus Municipality's consultation draft (see CD) on a future downtown school and on the publication "Model Program for elementary school 2010" (see CD), the report aims to answer the initial question:

How to create a framework that supports current and future needs of learning and how to integrate it into the dense area of Frederiksbjerg in Aarhus?

This project is conducted on the foundation of recent knowledge about educational values and architectural principles as well-being, differentiated teaching and age differentiation. Various case studies have also laid the groundwork for the project.

The report will result in a conceptual design for the urban planning of the area. The project zooms in on one of the three "districts"; primary school, middle school and final school, which will be explained later. Also a climate technical approach to the project is explored with the intent to develop a "healthy school" with a comfortable indoor environment in which important factors such as light, air and temperature are taken into account. The school should also meet the energy framework for 2010.

Ill. 1.2 360 degrees panoramic picture from Ingerslevs Boulevard

NEW SCHOOL IN THE DENSE CITY OF AARHUS

PRESENT AND FUTURE

Today the School of St. Annagade functions as a leisure center and the School of Kroghsgade functions as a school for children with special needs. The School of N.J. Fjordsgade is a municipal school with 745 pupils. Due to space constraints, the SFO is placed on Marselis Boulevard 52, together with a fourth grade and a 0-1. grade class for children with special needs.

For primary and middle school pupils both teaching and leisure is taking place at the School of N.J. Fjordsgade whereas the older pupils are attending the School of St. Annagade.
The functions of the School of N.J. Fjordsgade are scattered around the area reducing the sense a togetherness and diversity among the pupils. The vision for the new school is to merge these functions. The site must contain both a school building, an SFO and a leisure club. The buildings on N.J. Fjordsgade will be used as a community hall for associations and leisure activities. There will be an interaction between the two entities.
[www.aarhus.dk]

VISIONS FOR THE NEW SCHOOL

Aarhus Municipality wishes to create a new and modern school with future-oriented educational and technological solutions. This includes low energy use, good indoor climate and minimal CO_2 emission. The school building is to be open and invite the surrounding community inside to the benefit of the learning environment as well as the residents and users in the area.

The department of Children and Adolescent (Børn og Unge) in Aarhus municipality has the following visions for the new school:

1. The construction of a new city school on the site of today's School of St. Annagade and School of Kroghsgade.

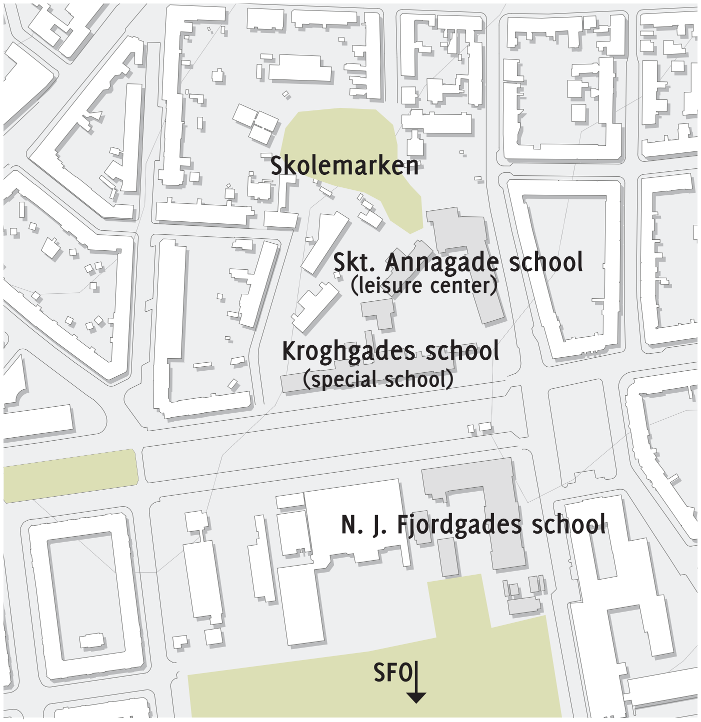
The new school must be world class and constructed in compliance with the latest standards for children environment and interior design of pedagogical and visionary learning environments.

2. Rather than just building a school the aim is to create an environment for children and adolescent in which the school can interact closely with the many services for children and adolescents around the St. Annagade site.
This enables the development of a strong environment for children in collaboration between the area's many leisure offers for children. It serves as an opportunity to work in unity and coherence witht the 0-18 year olds.

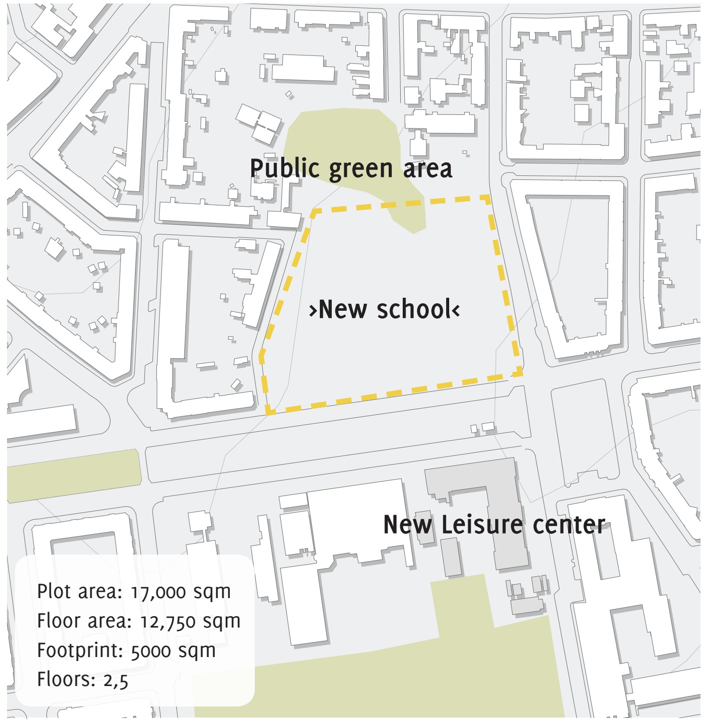
3. The small school can be incorporated in the big school - with separate sections that give special consideration to development of pupils in primary, middle and final stages of school.

4. The open space at the St. Annagade site (Skolemarken) should be maintained so that it continues to be an oasis, with free access for local residents.

5. As a supplement to Skolemarken the roof surfaces of the new school can become new outdoor activity space for sport and leisure. These can be designed and used by the school - possibly in cooperation with the Center for Recreational Activities (Center for Fritidsaktiviteter). [www.stiften.dk]



Ill. 1.3 Present situation



Ill. 1.4 Future situation

METHODOLOGY

NTEGRATED DESIGN PROCESS

During this project the Integrated Design Process (IDP) is used as method to gain an integrated and sustainable design solution. Since this project seeks to consider many different elements from both an architectural and an engineering point of view it is important that the process is managed methodologically. The IDP has an interdisciplinary approach that integrates research-based knowledge from engineering with architectural concerns to bridge the gap between the two professions [Knudstrup, 2010: page 3].

The IDP consists of five different phases that interconnect and relate to each other back and forth during the process. In the following the IDP is illustrated as a linear process but one must be aware that it is an iterative process that loops along the way.

DESIGN TOOLS

A combination of tools has been used for different phases of the process of creating a public building with a sustainable design and a healthy indoor climate.

Revit Architecture 2010 is a BIM (building information modeling) software developed by Autodesk. It is used for both 3D modeling and 2D detailing.

In order to design a public building in Denmark - Revit Architecture must be used as a tool. Using Revit Architecture 2010 for the last phase of this project will help to achieve more detailed and thought-thru concept.

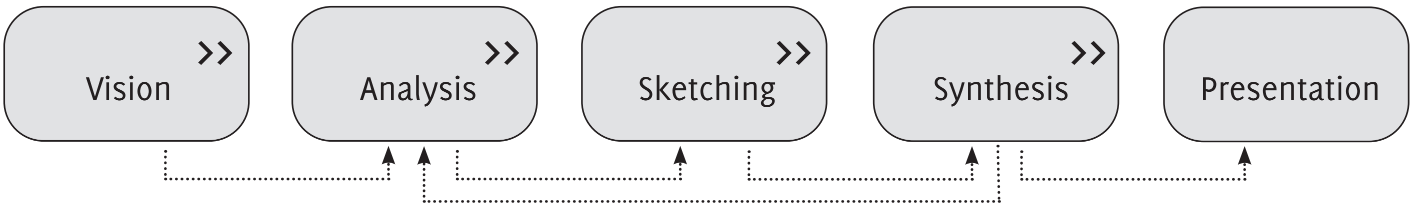
Virtual Environment (VE) is a plug-in for Revit Architecture 2010 software. This is a dynamic simulation tool, used to simulate energy use, indoor climate and light conditions, air flow. Furthermore program can be utilized for analysis of wind, solar and daylight.

This tool was chosen to work with since it is synchronized for usage with Revit Architecture 2010 and it can perform same calculations as Bsim. [gundog.lbl.gov]

Furthermore, VE has a potential to be used worldwide, because of growing popularity of Revit and all tools related to Revit software.

The software will be used during the whole design process, starting with initial sketching and ending with final indoor climate documentation.

BE10 - tool that will be used to document if the proposed design fulfills the demands of energy demands in Denmark.



Ill. 1.5 integrated design process
[Knudstrup 2004]

OBJECTIVE AND DELINEATION

PRESENTATION

ARRIVAL

In the middle of Frederiksberg in Aarhus the new Garden School rises on the corner of the big green Ingerslevs Boulevard and Skt. Annagade. In extension to the existing park, the school creates a lung in the city, that breaks with the linear and tall blocks in the residential area. The school's curved forms indicates, in conjunction with the mixture of glass and wood facade, that here is something different. Another pace, another scale and a place where life does not only happen inside the building but outside as well.

The school's main arrival area is through Ingerslev Boulevard. Parking area and school bus stop is located along Sct. Annagade which is a side street to the broad boulevard. This is where the parents have the opportunity to drop off their kids at the " kiss and goodbye" area.

The pedestrians are led directly to the school's main entrance, that invites the children inside through the small space created between two prominent building masses along the boulevard.

Near the main entrance it is possible to bike down a long ramp which leads down to the bike parking area hidden under the building. From here there is a second entrance to the school.

Another option for the children to arrive is through Sct. Annagade which is also where the area for goods delivery is located.

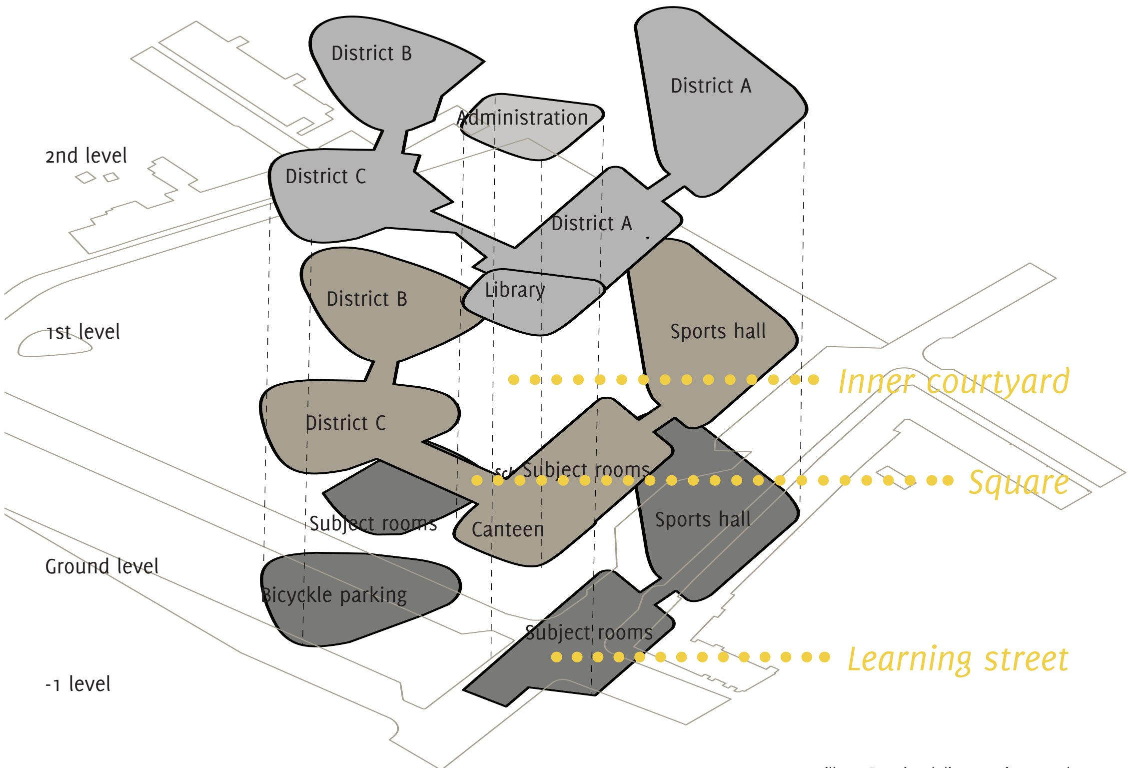
ill. 2.1 New Garden School in Frederiksbjerg, Aarhus

THE BUILDING

The school is placed on the site so that it faces both the arrival area, south and the garden, north. Facing the street is also the canteen/cafe, sports hall and the potential music and theater scene near the square which facilitates the school's more extroverted functions. The local citizens can therefore easily benefit from these functions.

Orientation through the building upon arrival is easy due to the the way the functions are laid out around the square and the central inner courtyard.

The way the buildings are laid out in an U-shape invites the landscape inside the school and creates a frame that integrates the close by nature in the education and life of the school.

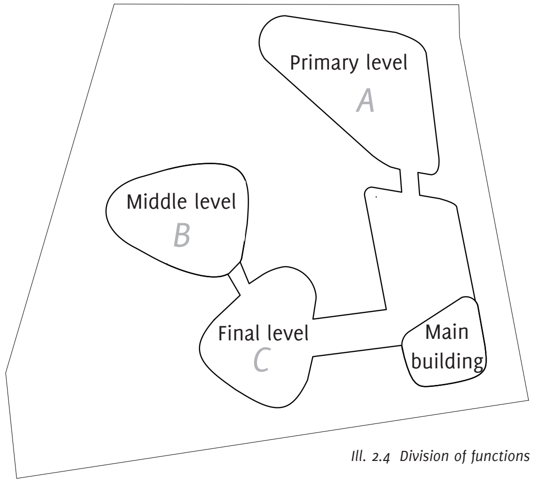


ill. 2.2 Functional diagram of proposal

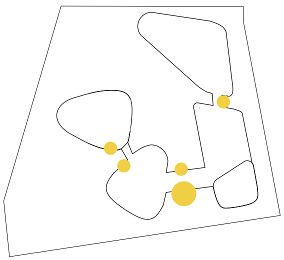
ill. 2.3 Entrance area

INDIVIDUALS - GROUPS - SCHOOL - CITY

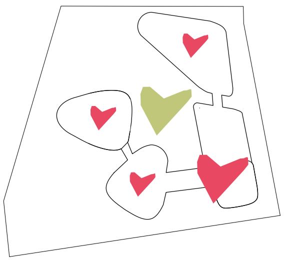
The school is structured around different degrees of community. The highest degree is at the square and the canteen. Next is the multi functional common room with designated areas for primary school, middle school and final school, last is the classroom's more intimate community. By creating different degrees of community, the foundation for interaction across the children's stages of growth are created.



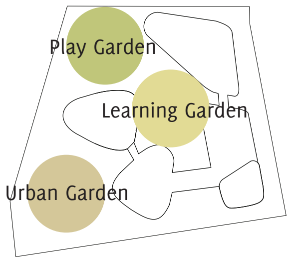
Ill. 2.4 Division of functions



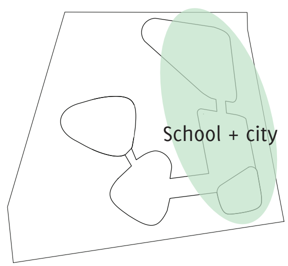
Ill. 2.5 Entrances



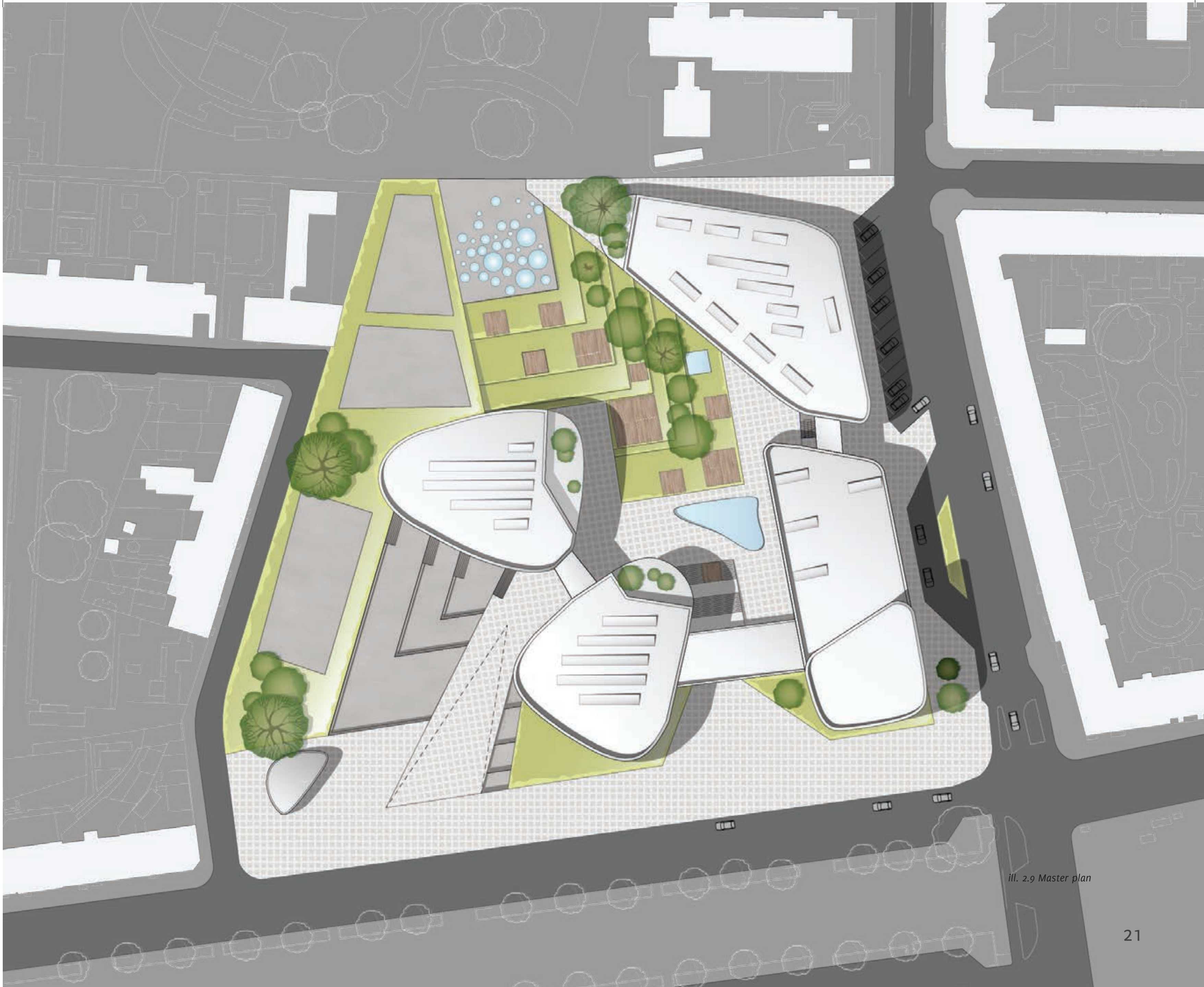
Ill. 2.6 Common areas



Ill. 2.7 Outdoor areas

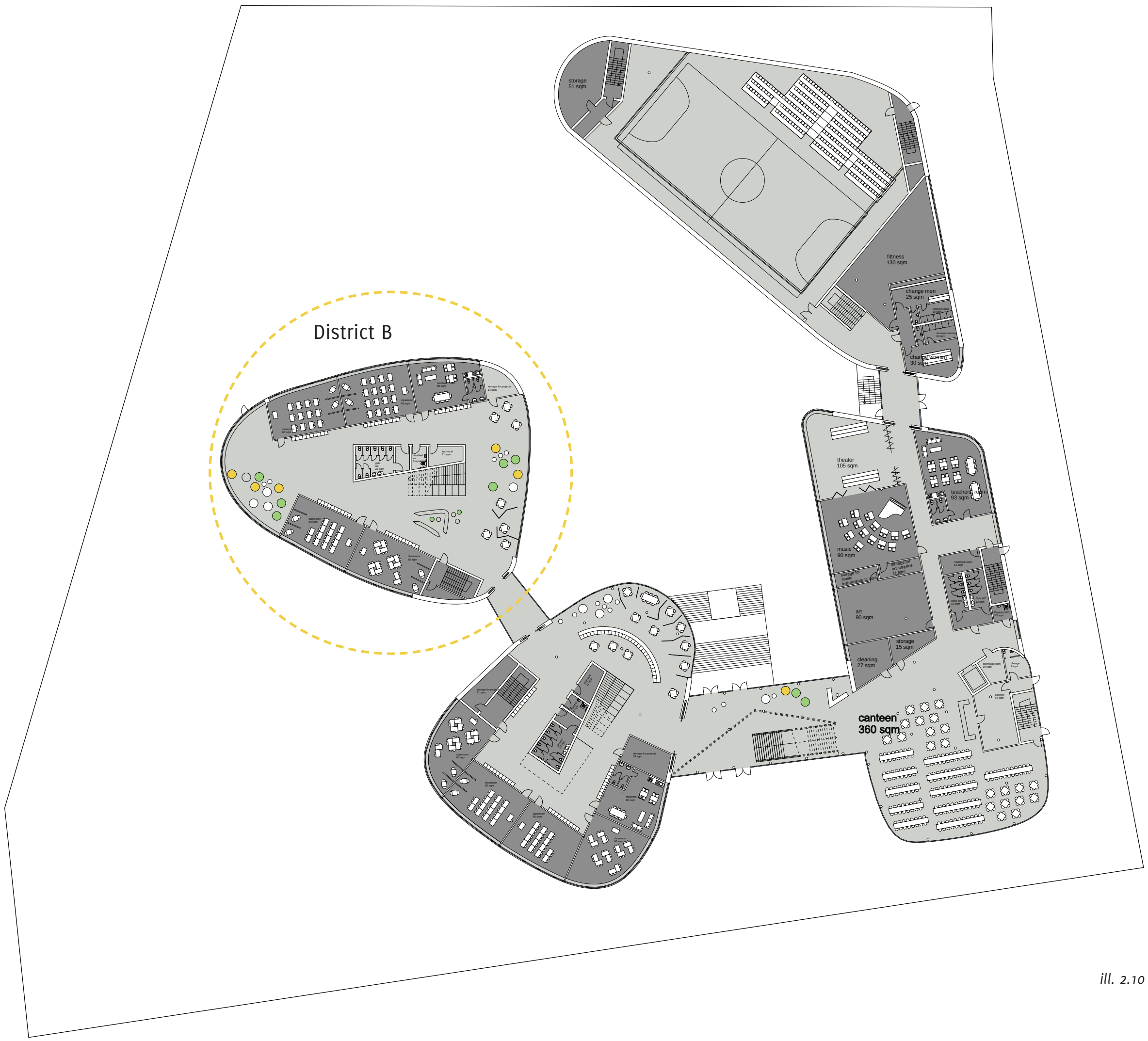


Ill. 2.8 Mixed functions



ill. 2.9 Master plan

THE DISTRICTS - ABC



ill. 2.10 School - 1 level

In the east wing the primary school (A) is placed while the middle school (B) and the final school (C) are placed in the west wing. Each of the areas is distributed on two levels and consists of classrooms, locker rooms, washrooms and store rooms which are located around a central common room. This enables interactions between the classrooms and opens up the area towards the inner green garden.

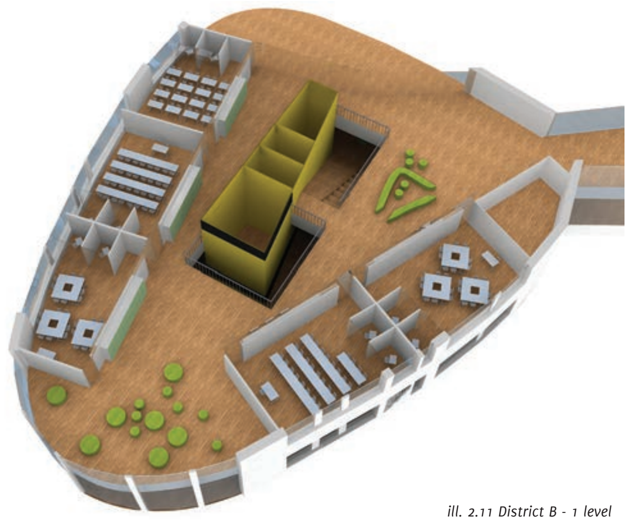
Districts A, B and C differs from each other by the common rooms gradually are becoming larger and gets more importance as the children gets older. By laying out the areas as separate areas creates a homely atmosphere for the pupils. It also creates a foundation for the teachers to organize grouped as well as smaller individual learning sessions.

In the designated areas the classrooms can act as small closed unities but they can also be opened up towards the common rooms. When the classrooms are closed they are still connected to the common rooms through the glass sections.

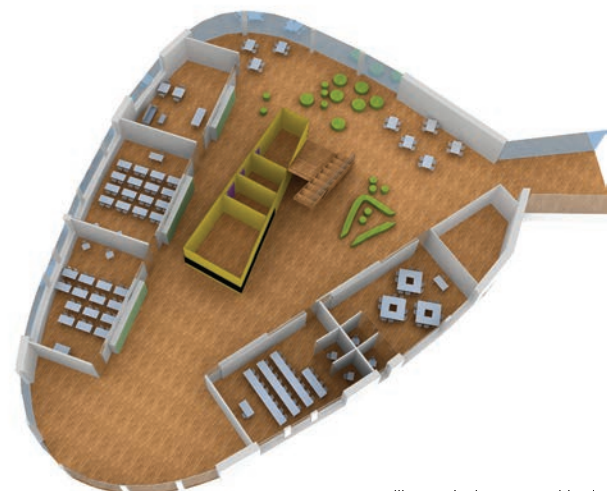
There are niches, nooks and workstations for smaller groups or individual immersion, in the common rooms in each area. To give the pupils the opportunity to create smaller spaces within the great room, a countersink is created with multifunctional portable wooden boxes that the students can work at, sit on or stack.

In the common rooms a multifunctional area is created where the pupils can borrow square meters from each other when the other classes are on field trips so that unused areas are avoided as often as possible.

The interior varies in the different districts. Because district A is integrated with the SFO there will be more room for play, while in districts B and C more focus will be on project work.



ill. 2.11 District B - 1 level



ill. 2.12 District B - ground level


They're
And FREE!!

ill. 2.13 District B - common area

LEARNING AND LEARNING STREET

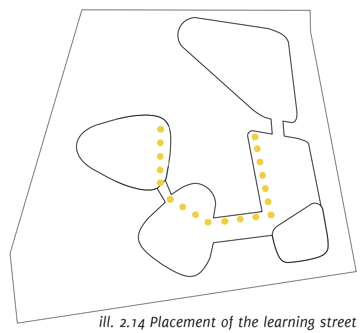
In the east wing the more public functions are placed such as the canteen/cafe, the library and the sports hall along with the school's administrative functions and the room for the employees.

The Learning street with the many special subject rooms is connecting the two wings and due to the room's openness an orientation toward the school's green heart, the garden, is created. The garden, along with the Learning street are sunk down a whole floor and forms an intimate outdoor space for the pupils.

The park invites to both movement, play and learning due to the close link between the Learning street's special subject rooms, the various activity and vegetation zones as well as the play and recreational areas, which are grouped in the central outdoor space with geometric platforms that are spread out in the area. The special subject rooms, which are grouped into the themes; science, art and culture, has large sliding glass doors that can be opened up to the courtyard, creating the potential for collaboration across disciplines and spaces. The rapid and smooth transition between outdoor and indoor increases the possibility to move the teaching outside linking the theoretical knowledge with more hands-on activities.

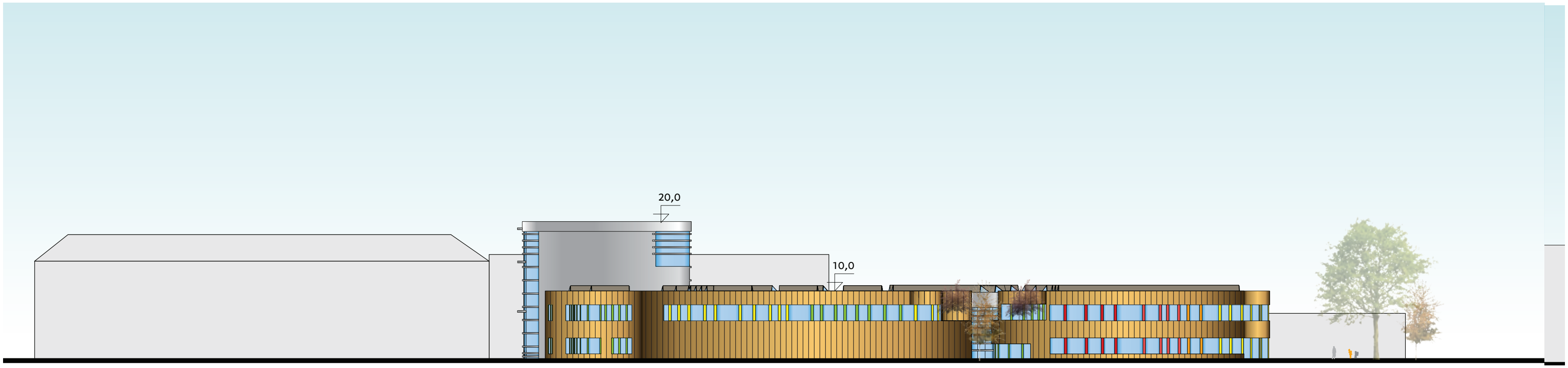
Although the school activities ends at about 4 pm the life continues in the building due to the public and easy accessible functions on the ground floor, which can operate independently from the rest of the school. The remaining and more private parts of the school are closed off and are only accessible with use of key cards.

The many experiences the school offers, both inside and outside, enhances the notion that each child must find their own way to use the school. The highly expressed lack of uniformity expresses a pedagogical practice that accepts that not all children are at the same level at the same time. Here the individual child will be given the opportunity to explore many different ways of learning and thus develop different approaches to learning that promotes engagement, well being and happiness.

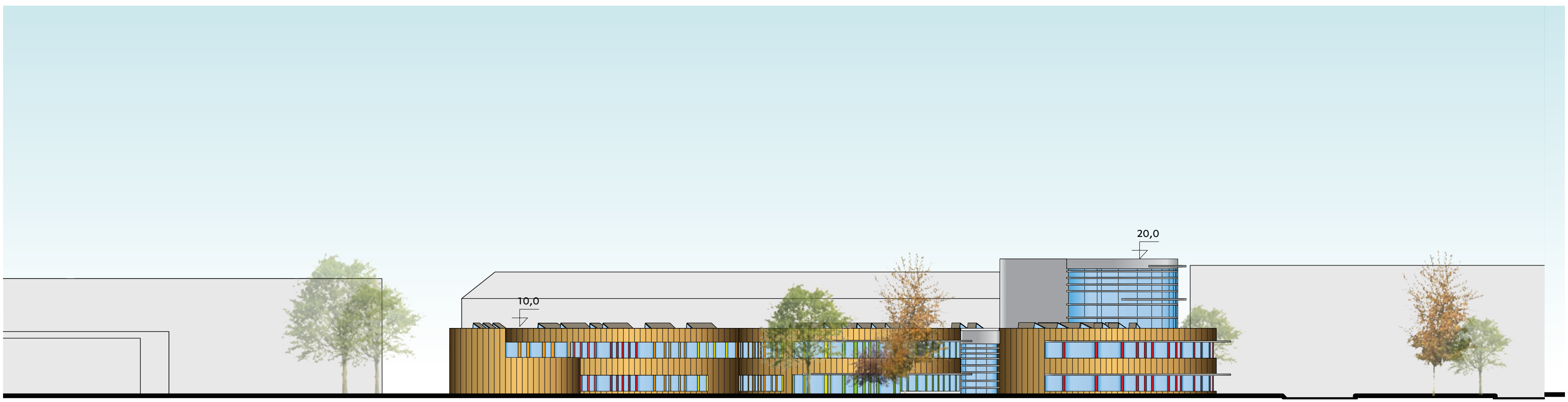


ill. 2.14 Placement of the learning street

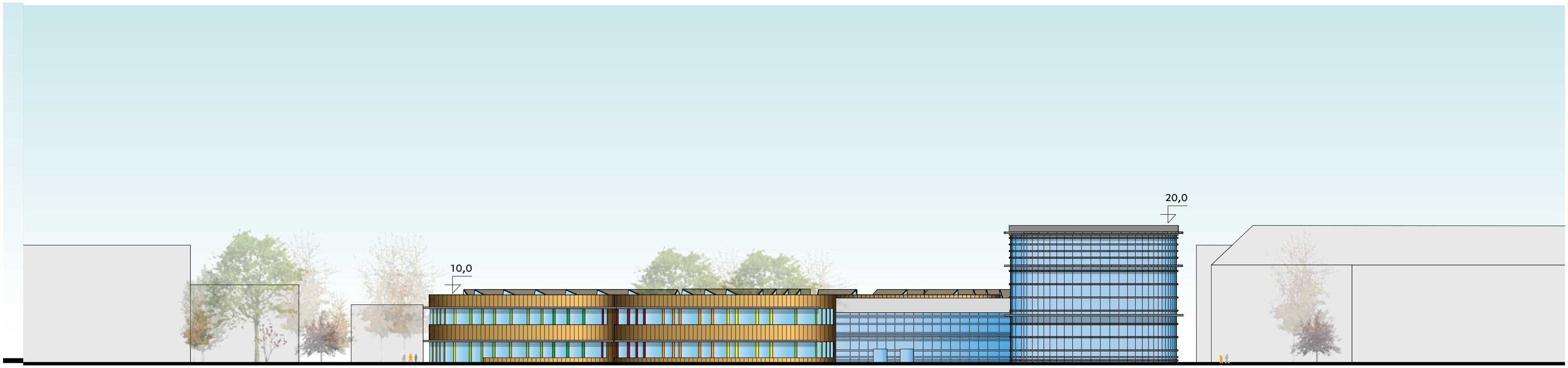
FACADES



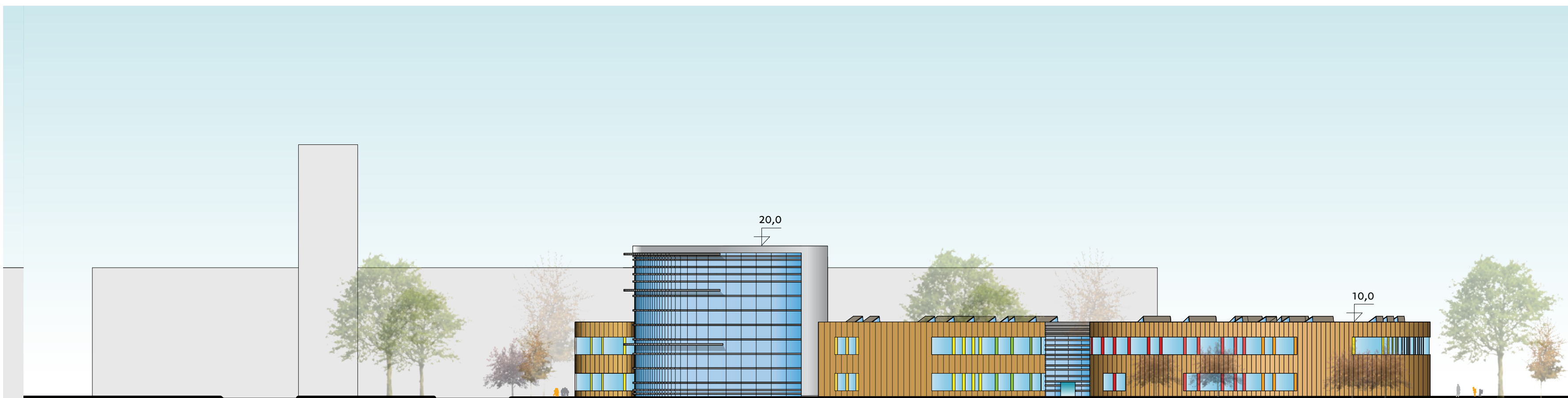
Ill. 2.16 North facade scale 1:1000



Ill. 2.17 West facade scale 1:1000

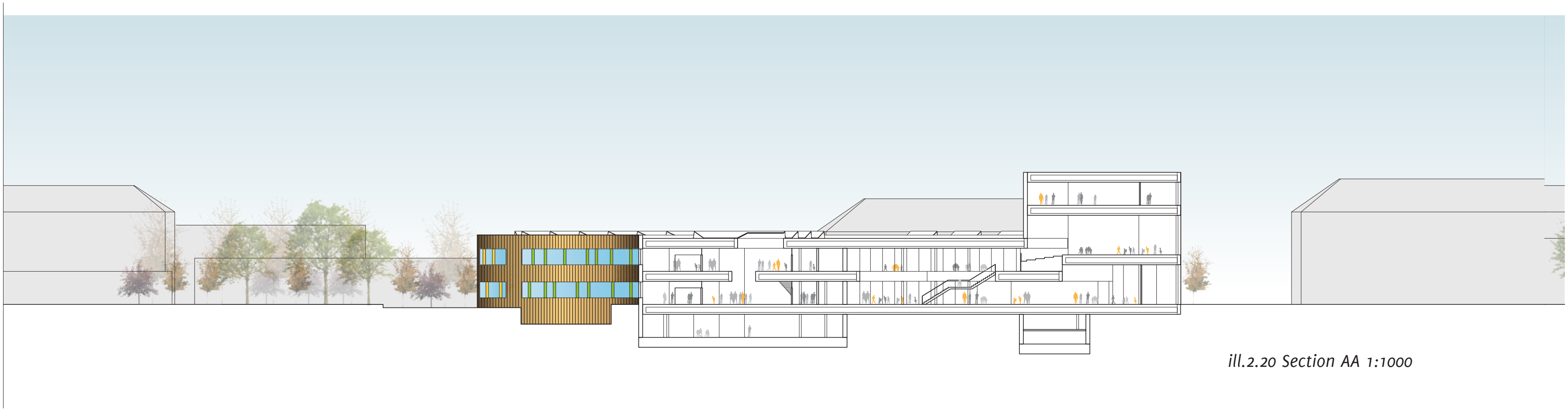


Ill. 2.18 South facade scale 1:1000

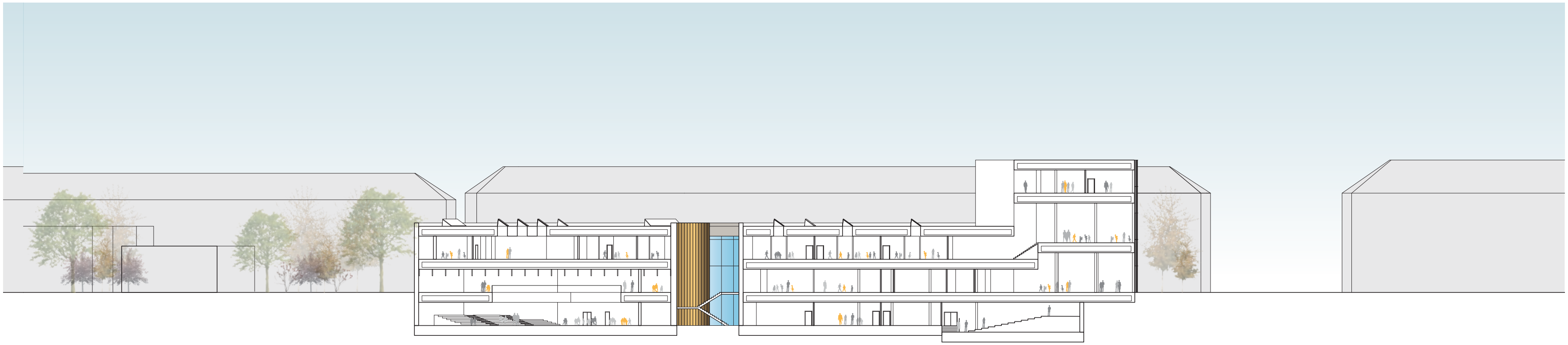


Ill. 2.19 East facade scale 1:1000

SECTIONS

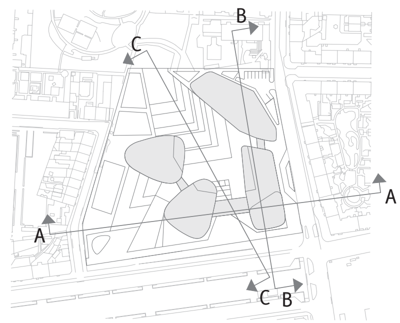


ill.2.20 Section AA 1:1000



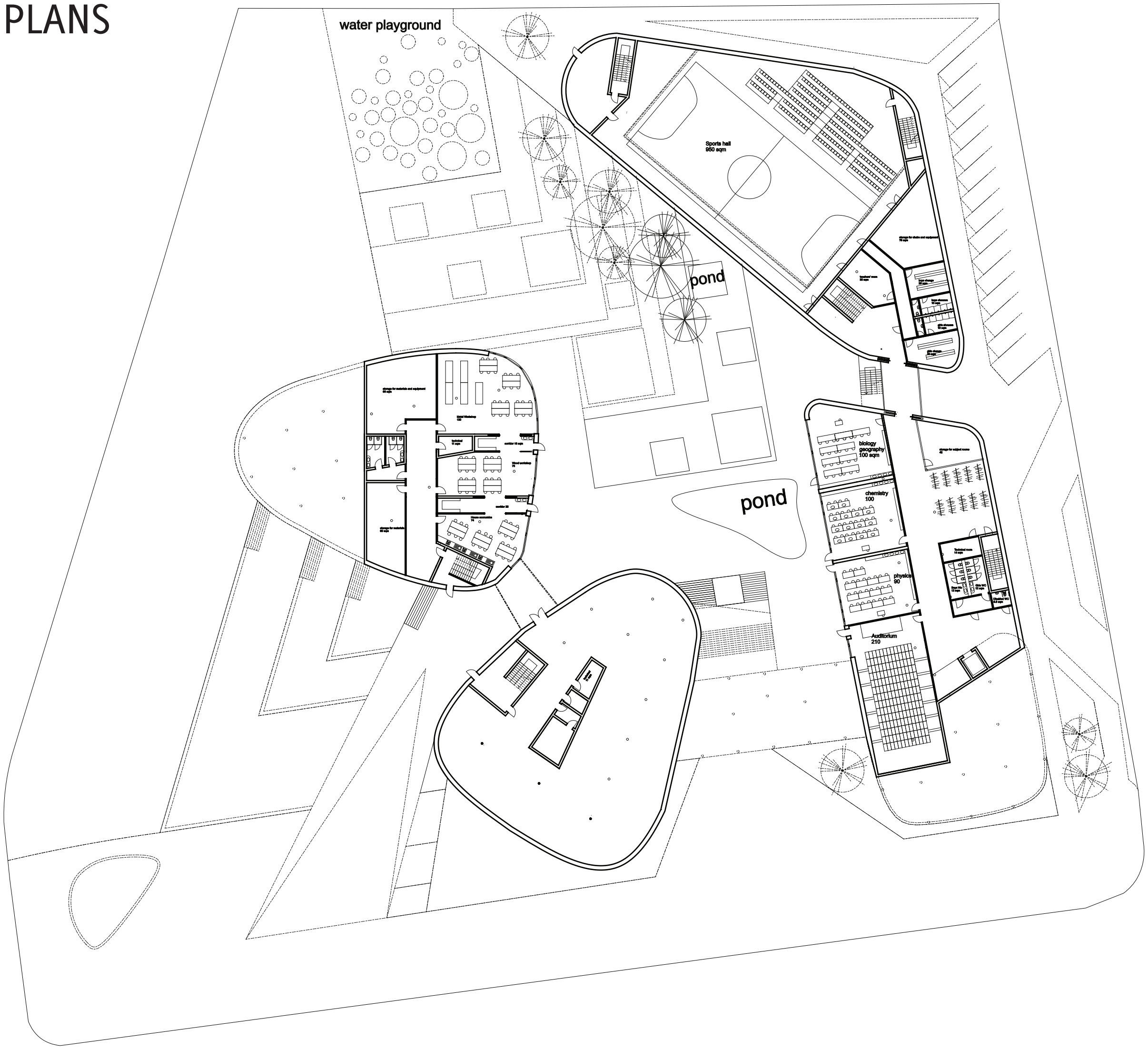
ill.2.21 Section BB 1:1000

ill.2.23 Section CC 1:500

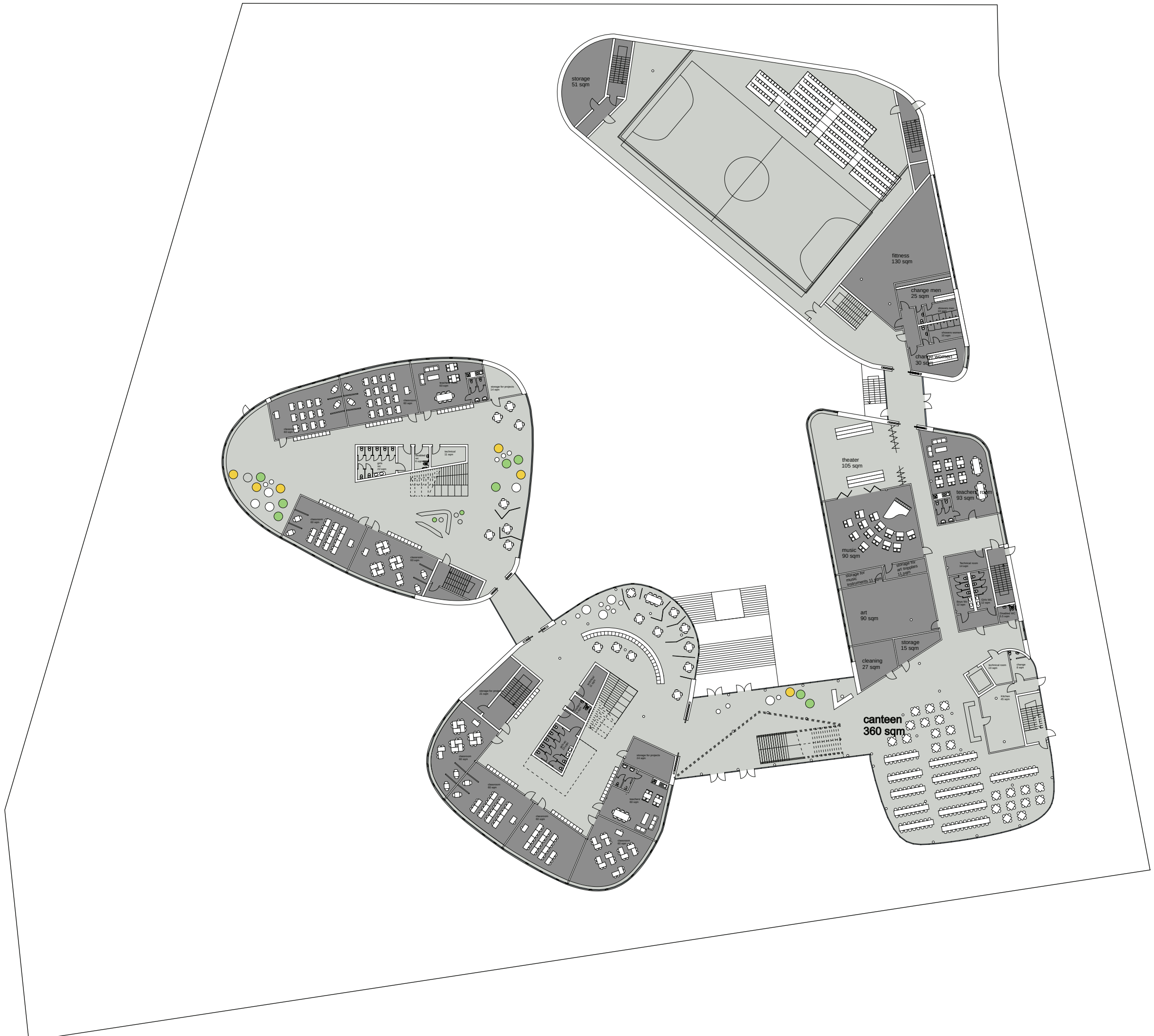


ill.2.22 Location of sections

PLANS

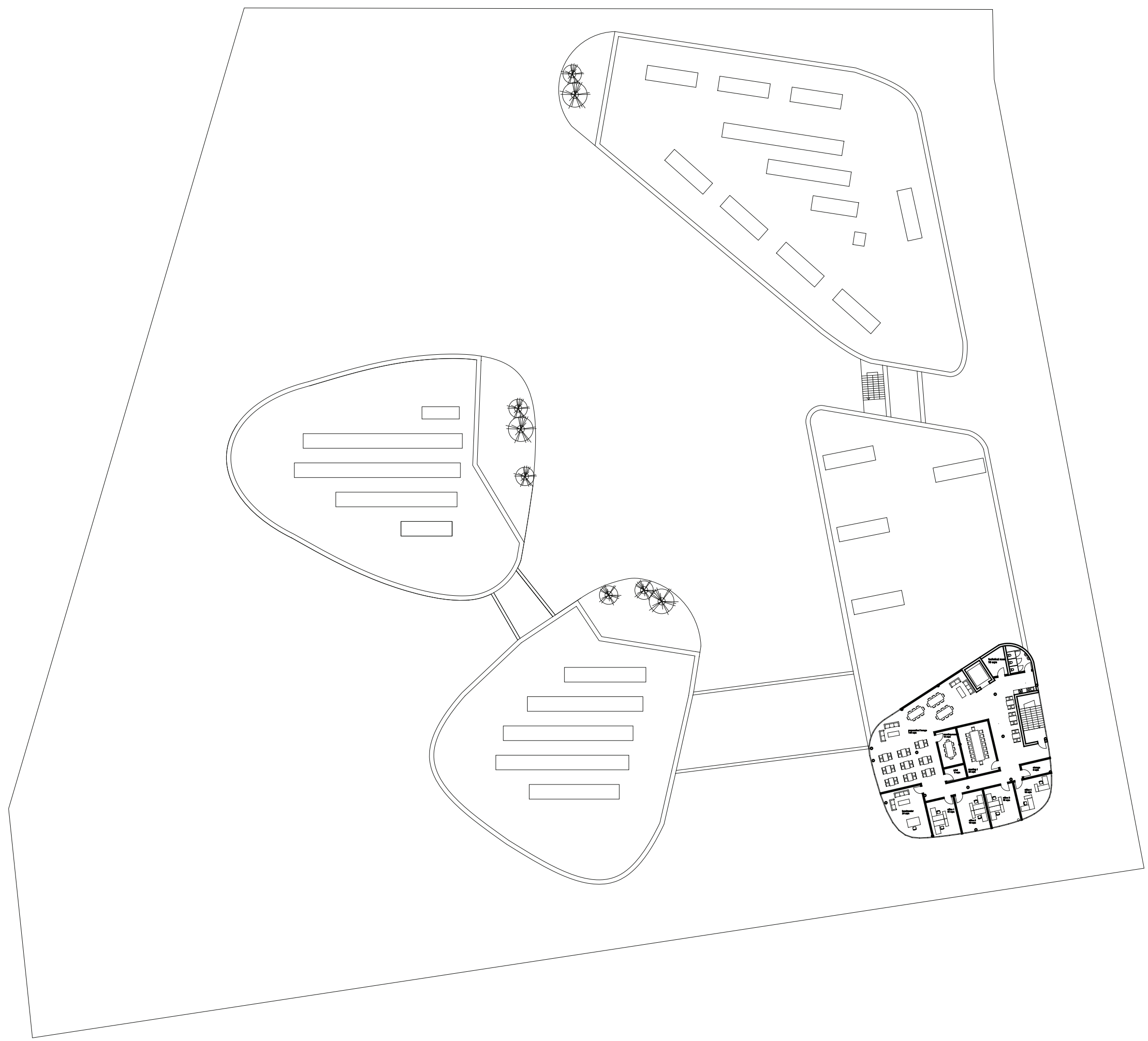


Ill. 2.24 - 1 level 1:1000



Ill. 2.25 Ground level 1:1000

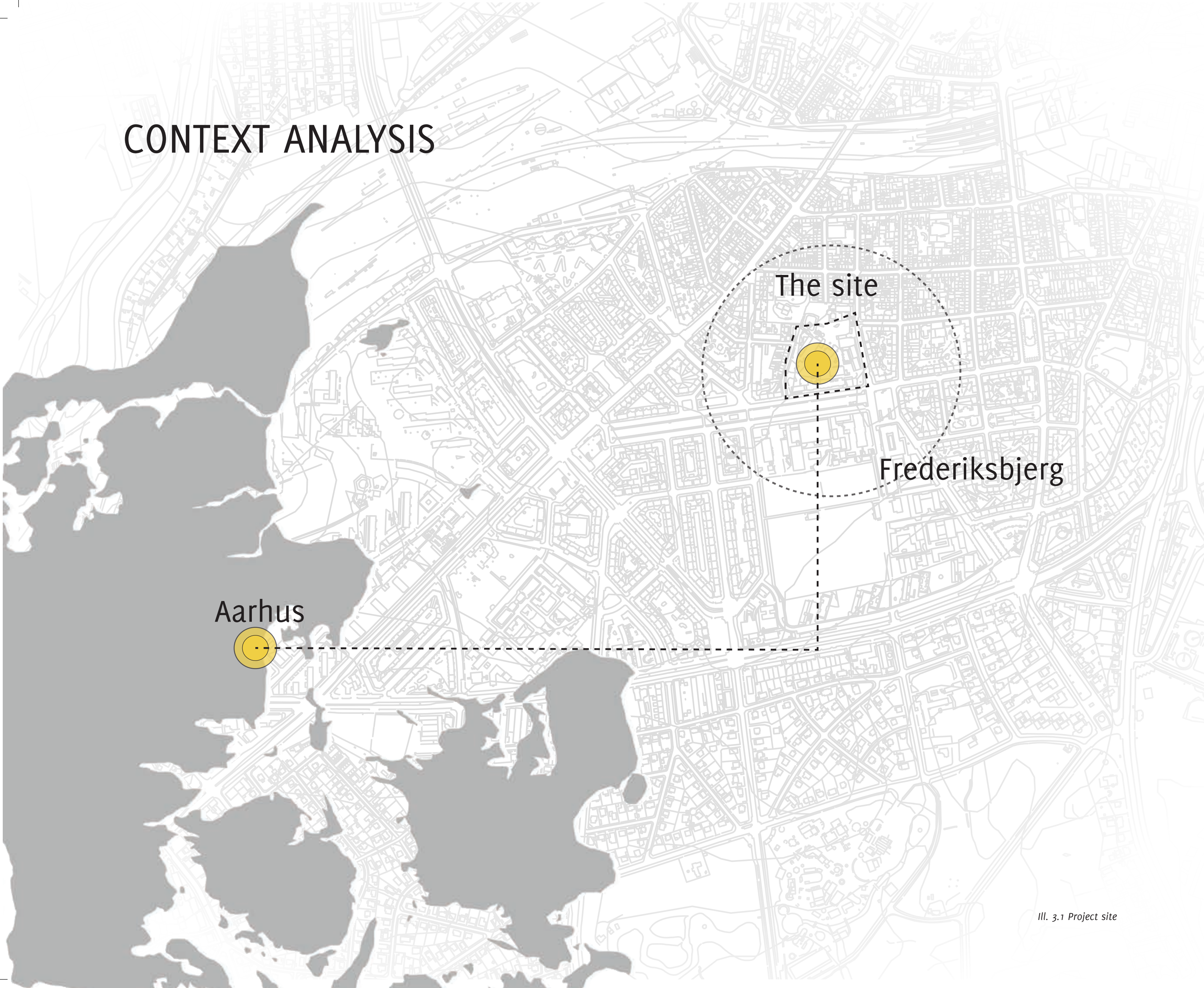
Ill. 2.26 1 level 1:1000



Ill. 2.27 2 level 1:1000

PROGRAM

CONTEXT ANALYSIS



Ill. 3.1 Project site

THE AREA

AARHUS AND FREDERIKSBJERG

Aarhus is Denmark's second biggest city with a population of 300,000 people. It is a young city, considering the average age of the inhabitants: every fifth citizen of Aarhus is studying in one of the 25 research or educational institutions [www.visitaarhus.com]. The large share of young people naturally creates a base of cultural activities. Cafes, restaurants, art galleries, museums and recreational areas are placed all around the city.

Aarhus is a growing city. Over the next 20 years the city must continue to grow – 75,000 new inhabitants and 10,000 extra students [www.aarhus.dk].

Frederiksbjerg is one of the boroughs of Aarhus, located south and within walking distance of the city centre. Bus and train stations are located north of the site within a 15 minutes walking distance. Within a radius of 1,5 km one can find beaches and city port and just south of the site is a forest and the Tivoli Park.

Ill. 3.2 Areal photo of Aarhus city

THE SITE

MAIN FUNCTIONS

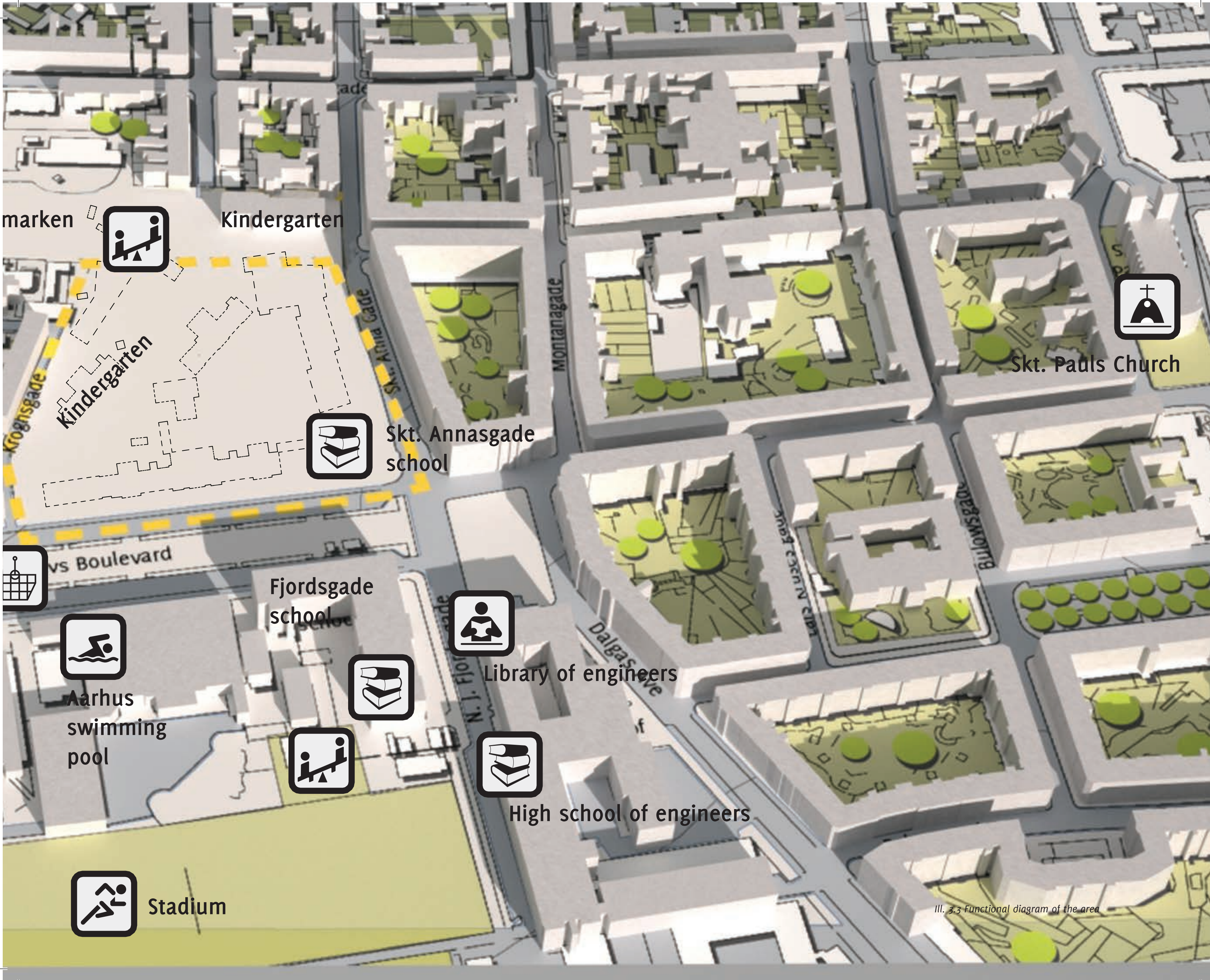
Frederiksbjerg borough consists of a great number of educational institutions from kindergartens to high schools. The area is lively all day long since different age groups, starting with small children to students are using educational facilities in the area. Sport facilities are used by local residents and guests all day long.

The School of N.J. Fjordsgade is adjacent to Ingerslevs Boulevard and just across VUC Aarhus (education institution for youth and grown-ups) and Aarhus Swimming Arena - also functioning as a public swimming pool. Further south is a school for engineers and the department of sports' science of University Aarhus. Football pitches cover a big area in the south.

On the building site itself School of Skt. Annagade and a few kindergartens are located. During the day the area is used by children while in the evenings the local community uses the buildings for meetings and various events.

Between the buildings different open spaces for skateboarding, football and playgrounds are found. The outdoor area is divided into different levels using stairs, creating a variety of smaller spaces with more opportunities and experiences for young people to use and play.

Mixed buildings with shops and cafes on the ground floor are placed in Frederiks Allé and M.P.Bruuns gade. That's where older children go for lunch during the breaks between classes. Another shopping spot is the parking lot at Ingerslevs Boulevard, which during the weekends is transformed into a market. Mostly food and flowers are sold there.



Ill. 3.3 Functional diagram of the area

GREEN AREAS

Because site is placed in a quite dense borough of Aarhus, it does not have much public green area such as parks or squares. Small islands with grass and trees are found all around the area, but mostly they are semi-private inner courtyards of the residential buildings.

An interesting recreational feature of the area is Skolemarken – a green oasis with a variety of playgrounds, located north from the project site. This feature will be described in detail later in the program (see page 47).

Football pitches cover a big area to the south. It is a semi public area, because in order to use it one must be a member of a sports club.

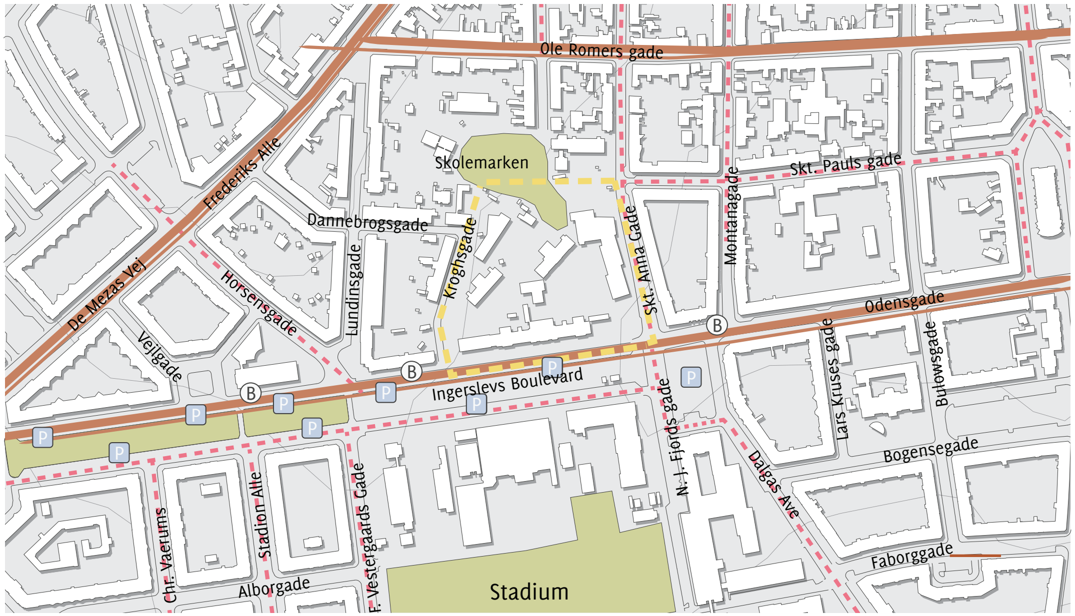
INFRASTRUCTURE

The traffic in the area is generally light, with Ingerslevs Boulevard being the busiest street. A lot of streets in the area have one-way traffic.

Part of Ingerslevs Boulevard is used as parking lot, with a capacity of 150 cars.

The site is easily accessible by foot or bike. Local residents and school children can also benefit from public transport, since there are several bus stops in the area and public transport is well developed.

In the morning traffic on Ingerslevs Boulevard is quite heavy since many parents bring their children to school by car.



Ill. 3.4 Infrastructure and Green areas

Main streets
Light traffic streets
Parking
Bus Stop
Public green areas

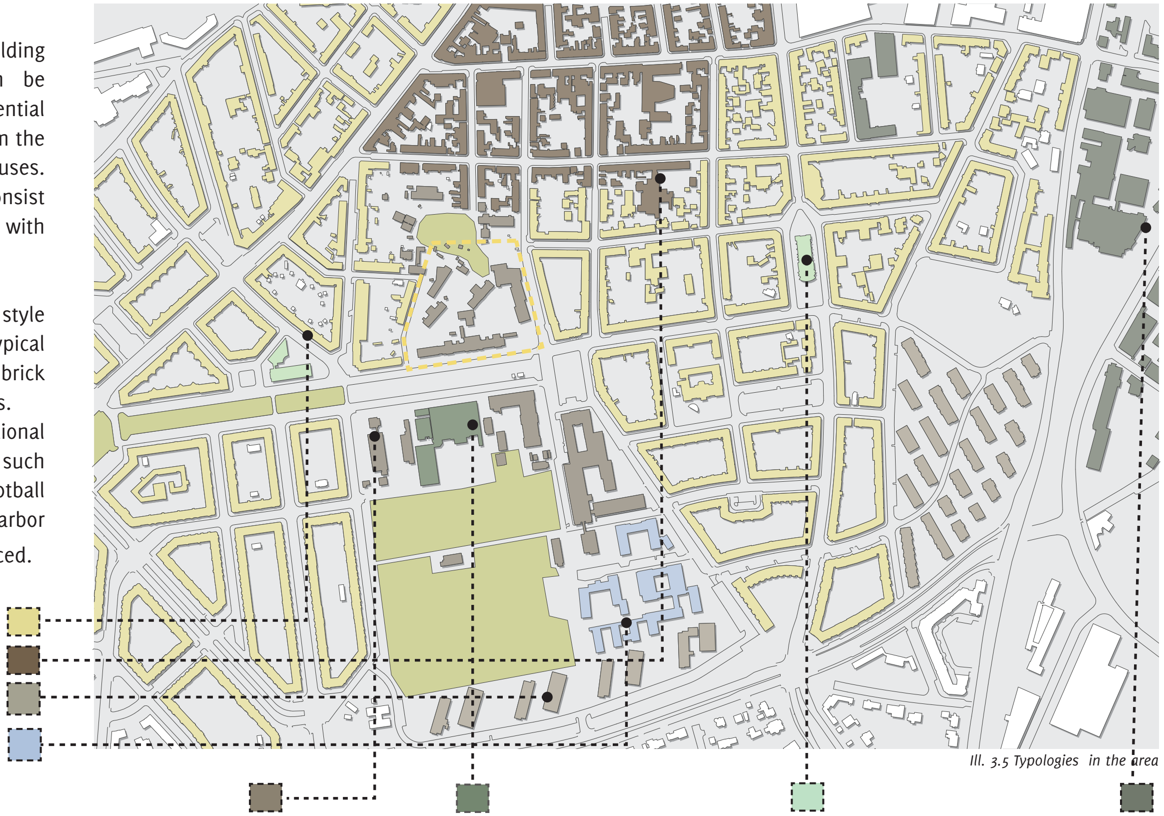
TYPOLOGY

Great varations of building typologies and heights can be found in the area. Low residential buildings are placed north from the site, mainly 2-3 storey town houses. Eastern and western parts consist of 5-6 storey karre structures with inner courtyards.

In general the architectural style dominant in the area is one typical for 1900's Denmark, with red-brick buildings and green courtyards.
The area is rich with educational buildings and sport facilities such as swimming pools and football pitches. Far east, where the harbor is, industrial buildings are placed.

Residential buildings:

- Blocks of flats, karre
- Low rise row houses
- Modern appartment blocks
- Dormitories



Ill. 3.5 Typologies in the area

Educational buildings

Sport buildings

Religious buildings

Industrial buildings

DISTINCTIVE ELEMENTS

Ill.3.6 Jaegergardsgade

Ill. 3.7 Row houses in Skt Anne Gade

Ill. 3.8 Ole Romers gade

Ill. 3.9 Residential karre buildings at Lundingsgade

Ill. 3.13 Playground and department of sports science

Ill. 3.14 School of Engineers

Ill. 3.15 Modern appartment blocks

Ill. 3.10 Ingerslevs Boulevard and N.J. Fjordskolen in the background

Ill. 3.11Skt. Lucas church

Ill. 3.12 Library of school of Engineers

Ill. 3.16 Yard of N.J. Fjordskolen school

Ill. 3.17 Yard of Skt. Annas Gade school

Ill. 3.18 Skatepark at Skt. Annes Gade school yard

Ill. 3.19 Football field with Aarhus University department of sports science building in the background

SKATEPARK

Since the 1980's the yard in th School of Skt. Annagade was a meeting spot for skaters. In 2000 the old "do it yourself" ramps and rough ground were redesigned by architectural company 'Nordarch and partners'. It was the first skate park in Denmark with concrete obstacles. Since the budget was very limited - asphalt was used for covering the ground, even thou it is not a durable material and not very good for skateboarding. The asphalt has already been replaced 3 times because the ground gets rougher every year. New plans for upgrading the skate park were developed in 2010, but they were stopped because of the municipality plan to redesign and renovate the whole school area.

The Skate Park is special since it was a successful and much used improvement of the area and a whole generation of Aarhus skaters grew up there. [www.nordarch.dk]

SPORTS FACILITIES

In 2007 the new building for Aarhus University department of sports science was finished. The building is located at Dalgas Avenue and provides students with modern and spacious research and teaching facilities.

The building is located close to the swimming pool. There are two pools, indoor and outdoor, the later used only in summer.

The football pitches belongs to the football club ASA. Members of the club have groups for both males and females of different ages, which practise in the football pitches.

Students attending the School of N.J. Fjordsgade are also welcome to use the football fields when they are not occupied.

SKOLEMARKEN

Skolemarken is a public playground open for all. From 10 am to 5 pm in weekdays a pedagogically trained staff is present at the playground. During this time the kids can visit goats in their fold and rabbits in the rabbit house. Children can have their own rabbit to take care of every day at the Skolemarken. There are also chickens, peacocks, parakeets and budgies.

These activities are however only a special offer for children/teenagers from 5th grade to 17 years.
For many children and adolescents Skolemarken is a place where they can hang out, talk and play, and it is a place where people can be together with friends and meet new ones.

SCHOOL OF N.J. FJORDSGADE

Built in: 1910
Number of pupils: 745
The School of N.J. Fjordsgade is a municipal school with children from preschool to ninth grade. The school is combined with an SFO where children from 0 - 4th grade attend.
The school is divided into four sections: primary (0-2 grade), middle (3-6 grade), final (7-9 grade) and a class for children with special needs.

Teachers and educators are only assigned to one department. This means that pupils get new teachers after the second grade and after sixth grade.

Ill. 3.20 Rabbit at Skolemarken

Ill. 3.21 N.J. Fjordsgadeskolen

CLIMATE

Ill. 3.22 Photo

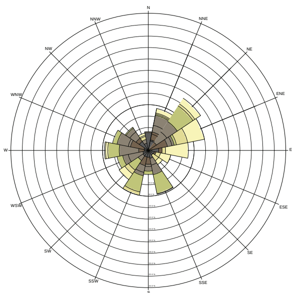
OVERVIEW

Local climate is explored and taken into cionsideration in order to design energy efficient buildings and to create healthy indoor environments.

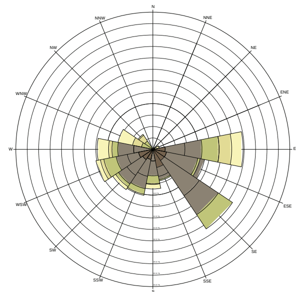
WIND

The wind roses illustrate that wind conditions change a lot during the year. In the spring and autumn north east, east and west east winds are dominant, while in the summer and winter the dominant winds western winds are common.

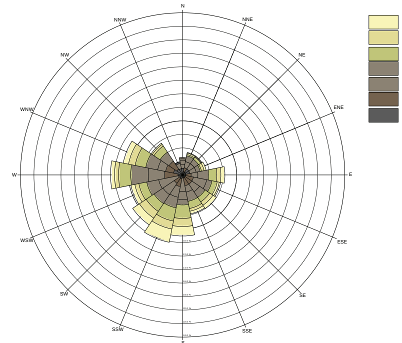
Strong winds, with a speed above 25m/s, are more common in March and December.



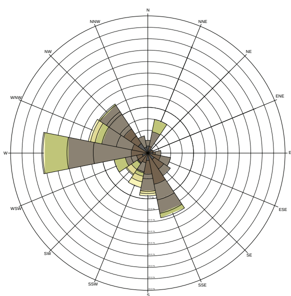
Ill. 3.23 Wind direction distribution ***March***



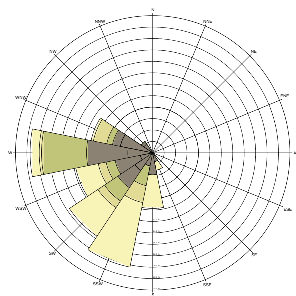
Ill. 3.25 Wind direction distribution ***September***



Ill. 3.27 Wind direction distribution ***year***



Ill. 3.24 Wind direction distribution ***June***



Ill. 3.26 Wind direction distribution ***December***

TEMPERATURE

Like most of Denmark, Aarhus has a maritime, temperate climate. The weather is typical Scandinavian with cold winters and tempered summers.

February is the coldest month (avarage temperature -1.2 degrees Celsius) in Aarhus, while July is the warmest (avarage temperature -19.5 degrees Celsius). [www.visitaarhus.dk,weather]

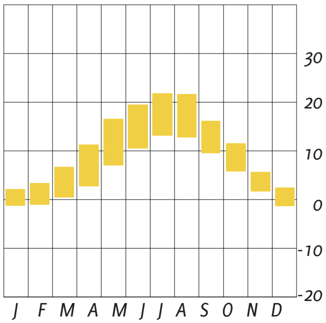
Rainfall varies from 114.0 to 261.0 (mm/month).

SUN

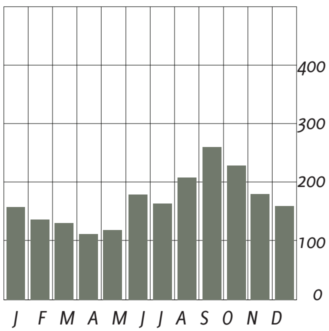
The diagrams on the far right illustrate sun angle and length of the day at selected dates in each of the four seasons. During the winter the sun is low and sun rays can penetrate through the windows deep into the building. Unfortunately the length of the day in the winter time is short (around 7 hours in December), which limites the possibilities of natural light and solar heat indoor. During the summer the angle of the sun is high and the days are longer (up to 17 hours in June). Overheating problem occurs. It should be solved using chosen strategies during the initial sketching phase and later.

SHADOWS

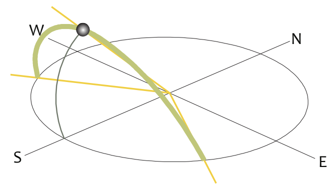
A 3D model of the site and its surroundings has been built to investigate the effect of neighboring buildings to the building site. Surrounding buildings are not very high (from 2 floors on the west side of the site, up to 6 floors on the east). But still in the evenings and mornings, especially in spring, autumn and winter they cause long shadows on the west and east sides.



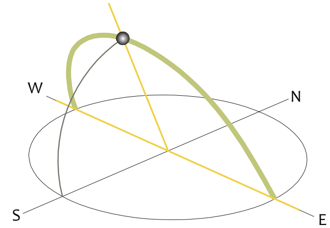
Ill. 3.28 Temperatures



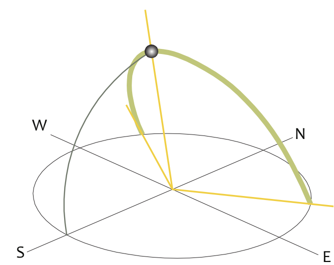
Ill. 3.29 Rainfall



Ill. 3.30 Winter solstice December 21st



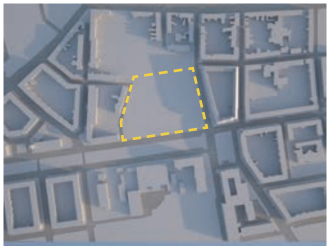
Ill. 3.31 Spring/fall equinox March/October 21st

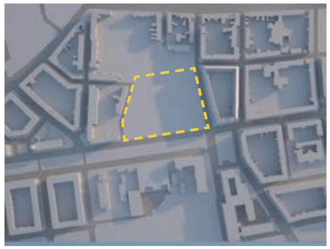


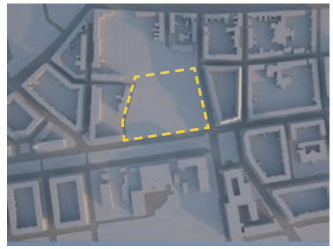
Ill. 3.32 Summer solstice June 21st

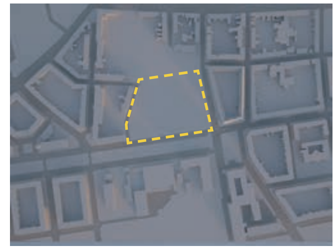
March 21 | June 21 | October 21 | December 21

Sunrise

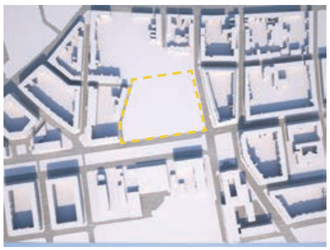

Ill. 3.33 07.30 [sunrise 06.10]


Ill. 3.36 05.00 [sunrise 04.25]

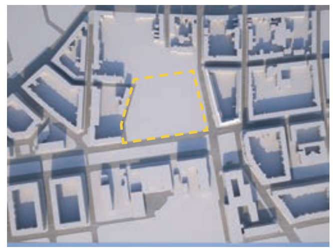

Ill. 3.39 08.10 [sunrise 07.52]

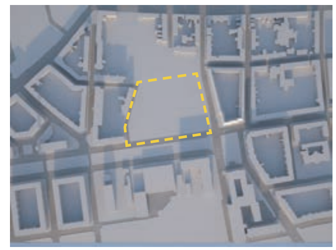

Ill. 3.42 09.40 [sunrise 08.37]

12.00

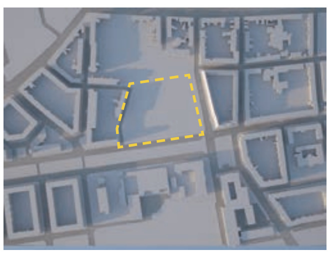

Ill. 3.34 day length 12h15min


Ill. 3.37 day length 17h32min


Ill. 3.40 day length 10h03min


Ill. 3.43 day length 07h00min

Sunset


Ill. 3.35 17.00 [sunset 18.25]


Ill. 3.38 21.00 [sunset 21.58]


Ill. 3.41 16.50 [sunset 17.55]


Ill. 3.44 14.30 [sunset 15.38]

Shadow studies

SCHOOL ARCHITECTURE
DANISH SCHOOLS AND PEDAGOGICAL PRINCIPLES OVER TIME

The concept of the good school changes over time. This applies both to the approach to how children learn and what they need to learn.

Tuition is now more oriented towards the individual pupil and his or her prerequisites than a few years ago, and a growing emphasis is put on working practices and project oriented work. The school day is less scheduled, and the school's physical environment must accommodate a diversity of work styles and work flows. The school is no longer a static concept.

One of the means to target teaching to pupils' individual abilities and needs is differentiated teaching. In recent years focus has increasingly been on `multiple intelligences' and `various learning styles'. This means that we can not just focus on the academically oriented learning processes. The pupils must also be given the opportunity to work with their bodies and hands. In short, pupils must be given the opportunity to acquire knowledge in the ways they learn best and most.

The underlying understanding behind these demands for public schools is partly due to changes in the perception of how we construct and share knowledge. Knowledge is no longer seen solely as something that can be handed from one person to another, but rather as something people construct together. [Kirkeby 2006: p. 11].

THE ARCHITECTURAL CHALLENGE

Today's schools are expected to balance between factual learning and self-production of knowledge, between the classroom tuition/team tuition and individual assignments, and between the quiet reflection and physical activity. Many of these diverse activities create a need for increased spatial and functional flexibility in the construction and interior design of school buildings. This is a need that traditional classrooms and school buildings have difficulty in meeting. ["Model Programme for public schools" 2010: p. 9]

Quotes from the Primary Education Act:

"The organization of the teaching, including the choice of teaching and work styles, methods, teaching materials and subject selection, must in all courses respond to the purposes of the public school and vary so that it corresponds to the individual pupil's needs and qualifications."

[Primary Education Act § 18 paragraph. 1 - 5, 1993]

Ill. 3.45 N.J. Fjordsgadeskolen

SPACE AND LEARNING

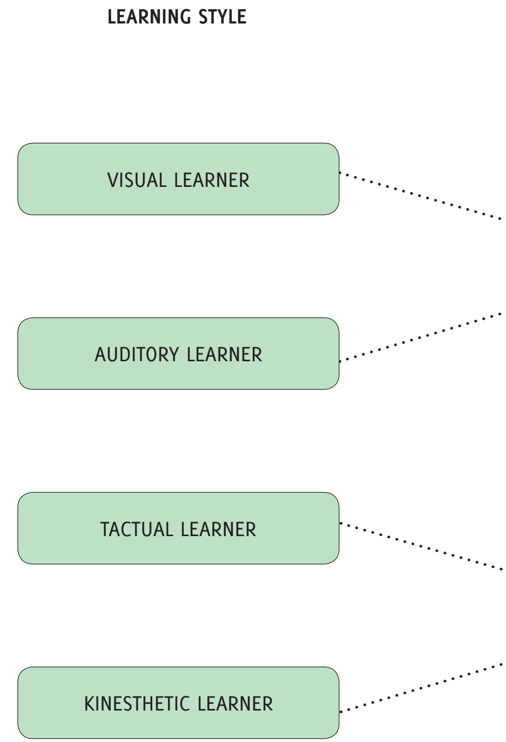
DIFFERENTIATION OF TEACHING AND LEARNING STYLES

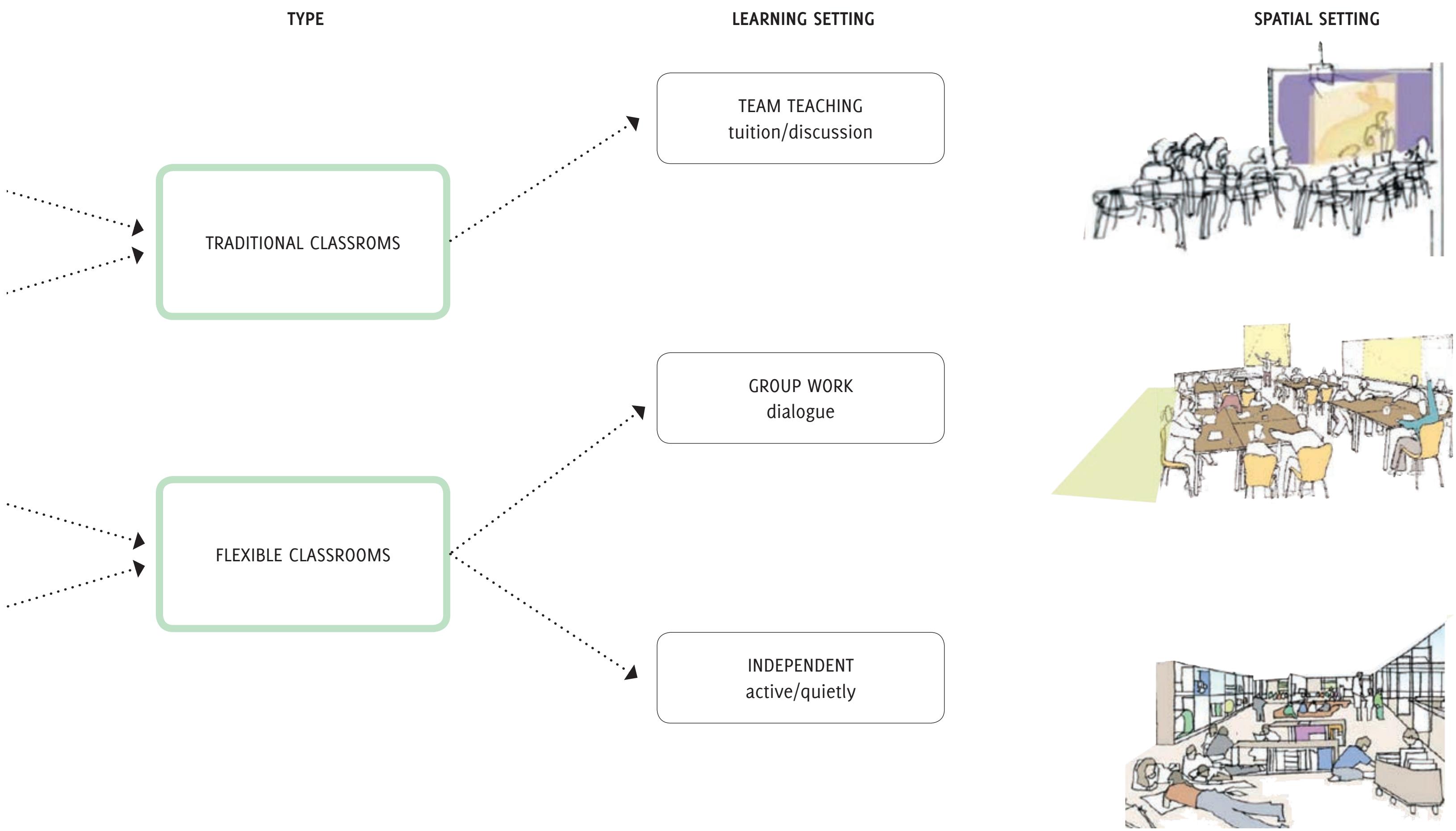
To meet the increased focus on individual learning needs the Children and Youth Committee in Aarhus Municipality plans to implement two educational theories called “differentiated teaching”and “learning styles”.

Differentiated teaching is a flexible way to structure teaching and learning. It ensures that pupils are approached where they are ready to learn. Working with learning styles means that the fact that children learn in different ways is appreciated. Once the pupil has to learn something new - something that is seen as difficult – considerations are made on how each pupil receives new input. [Consultation Draft 2010: p. 12]

Together, differentiated teaching and learning styles provide the opportunity for the child to experience success and to thrive.

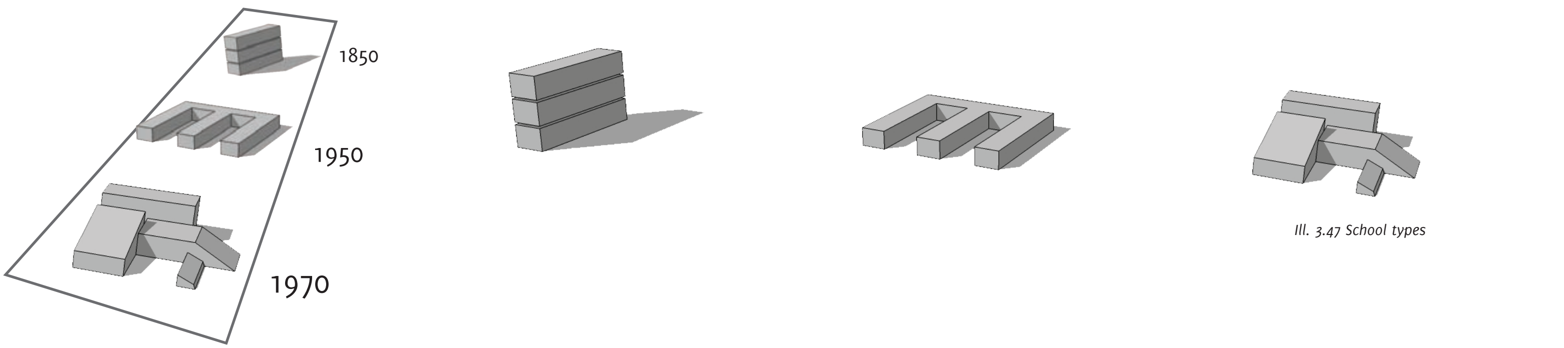
Some children learn best through dialogue, others need visual calmness and no noise. Some children find it hard to concentrate if they have to sit on a chair, but can read for hours when they lie on the floor. The American professors Rita and Kenn Dunn categorizes teaching methods in four areas: auditory, visual, tactual or kinesthetic learner. Few, however, are auditory oriented, even though that is the teaching method which has been traditionally used and is still used in the Danish school system. [www.learingsstile.dk]





Ill. 3.46 The Diagram shows the four learning styles and examples of different learning environments

SCHOOL TYPOLOGIES



Ill. 3.47 School types

CHARACTERISTICS

In Denmark various types of schools have been built. However they can be divided into three main building types each with its own characteristics. The three types of school buildings reflect different pedagogical principles and learning environments which can give a rough understanding of the development, use, preferences and experiences through time.

The Multiple Floor School

› 1850 onwards
› Typically 3-4 floors
› Location in city center
› Access from a central entrance
› Corridors with cell-like classrooms and subject rooms placed along them.
› Small classrooms, and many square meters used on staircases and corridors.
› Outdoor areas are often paved.
› Learning Principle: From an exalted podium the teachers forward knowledge to the sedentary pupils.

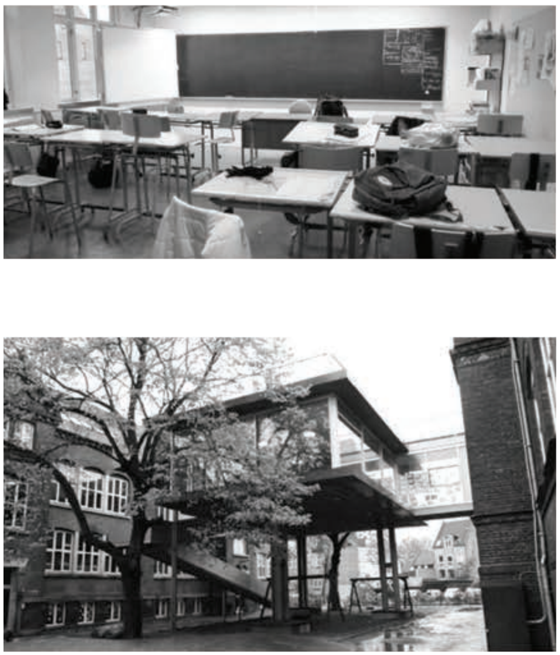
The Function-segregated School

› 1950 onwards
› One floor
› Location in city outskirts
› Shaped like a comb. Each arm has a specific function such as classrooms, subject rooms or staff rooms.
› Spread over many square meters and characterized by long corridors and large distances
› Large common areas
› Large outdoor areas for play and sports
› Learning Principle: Teachers and pupils are more equal

The Spatial-flexible School

› 1970 onwards
› Open-plan school
› Divided into smaller “home areas”. One home area hosts several classes and grades.
› Inventory can be moved
› Alternating in work form between classroom instruction, team teaching, individual work, teamwork and project work across classes.
› Learning Principle: Learning should involve cooperation between pupils and teachers

This analysis of school typologies is based on the project “Model Program for public schools “ from 2010, as developed by The Danish Enterprise and Construction Authority (Erhvervs- og Byggestyrelsen) and Realdania in collaboration with KL. The project illustrates the development of public schools and draws on case studies of various school buildings. [“Model Program for public schools “ 2010: p. 26]



Ill. 3.48 and 3.49 Example of a Multiple Floor School

Ill. 3.50 and 3.51 Example of a Function-segregated School

Ill. 3.52 and 3.53 Example of a Spatial-flexible School

SCHOOLS FUNCTIONS AND AREAS

The charts to the right represent the three school typologies; The Multiple Floor School, The Function-segregated School and The Spatial-flexible School.

As shown, the three types of schools distribute their square meters widely different from each other. While the share of square meters for classrooms is greatest in The Function-segregated School, the share of square meters for common areas is greatest in The Spatial-flexible School. Common areas have eventually gotten more attention because of their flexibility and options for different usage situations, and are therefore assigned a larger percentage of the total area. The relation between the functions "Others" and "Employees" are in turn largely constant at all school types, which emphasizes the importance of the dynamics between common areas and teaching.

COMMON AREAS

The category of "Common areas" applies for multiple types of usage and is therefore further divided into the subcategories Common areas/ Corridors, Corridors, Educators center/Corridors and Corridors/Lounge. This is explained in the illustration for the three schools. Here we see that in The Multiple Floor School traffic is distributed in the staircases and corridors, while the amount of square meters unsuitable for anything other than transport corridors are reduced drastically in The Spatial-flexible School.

SHARE PER STUDENT

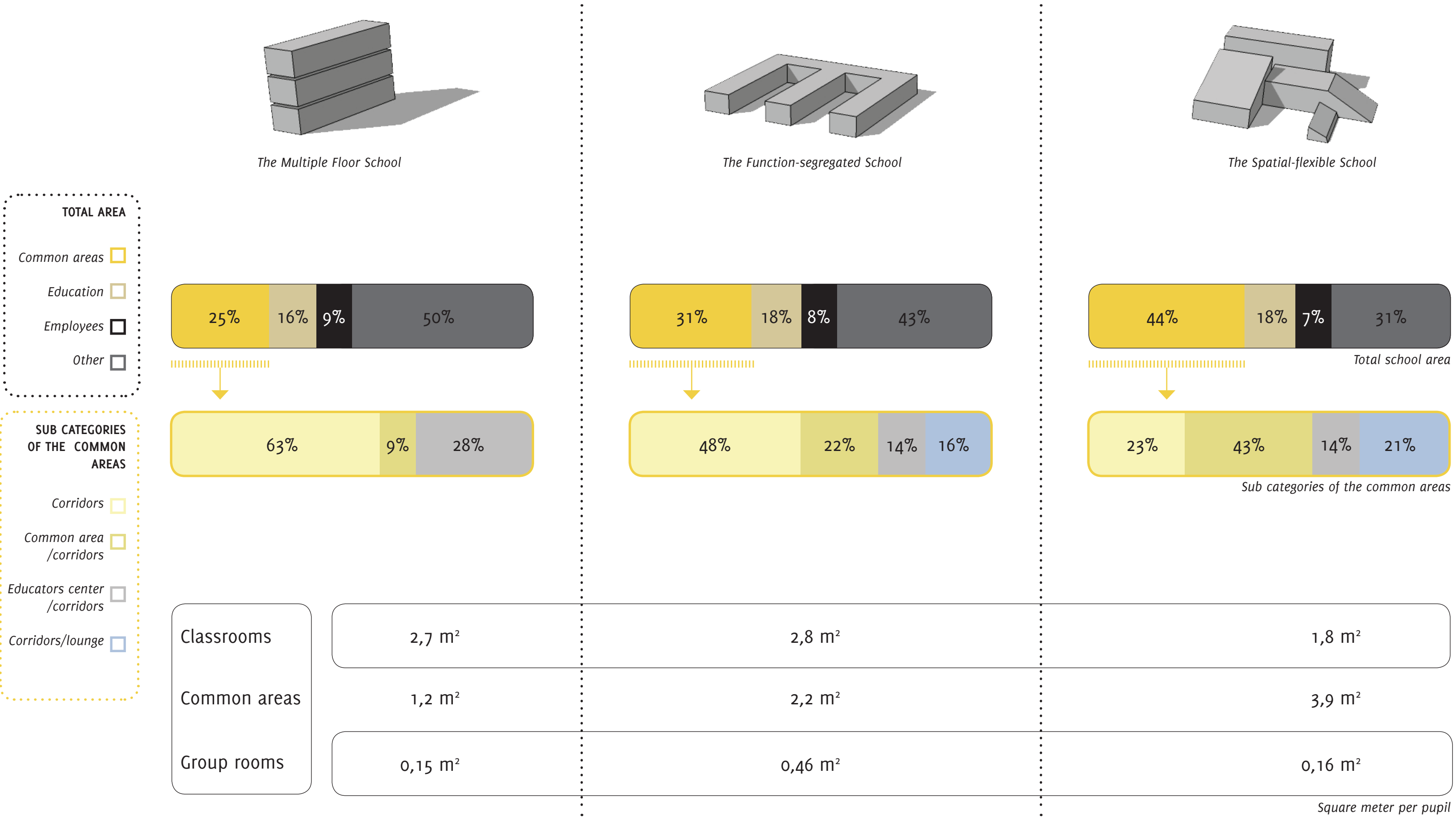
The bottom of the chart shows that each pupil has a class share (class ratio/area) of 2.7 square meters in The Multiple Floor School, 2.8 square meters in The Function-segregated School and only 1.8 m2 in The Spatial-flexible School. In The Spatial-flexible School the class share is thus reduced by about a third compared to the other two schools. Significantly more square meters are used for common rooms to compensate for the lower class share – but this makes quite special demands for the common rooms to function optimal as workspace for students. ["Model Program for public schools " 2010: p. 28]

THE CHALLENGE

The lessons learned from the different types of schools shows that learning context has changed, and along with it so has the physical environment itself. The problem is that traditional classrooms and long corridors restrict the teaching and reduce the pupils' opportunities, while open-plan teaching environment don't accomodate the weak students and their needs for defined space. Also the open-plan type impose extra challenges for the teacher-pupil relation.

The great architectural challenge seems to be to ensure that the physical conditions outlives the reigning educational vision. In this context the concept of flexibility has become a key topic during the last decades of school construction. Usually the "open plan solution" is chosen which is based on flexible walls, flexible furniture and other degrees of flexibility. This flexibility, however, is rarely utilized and " the open plan solution" also creates significant challenges in how to organize the daily teaching.

Instead of working with flexibility as a way to furnish a room, this project aims to create a *spatial* diversity, which can meet the school's diverse needs - spaces for learning, for play and for social interaction.
The following pages are based on some of today's most important pedagogical principles; differentiated teaching, wellbeing and age differentiation.



Ill. 3.54 The diagram shows a space analysis of the three types of schools ["Model Program for public schools " 2010: p. 29]

FOCUS AREAS

"Modern teaching methods, with the traditional classroom with tables and chairs in rows playing an increasingly smaller role, require other physical facilities and structures than was built in 1910. The pedagogical design of the elementary school of the future should be able to accommodate and match the great variability, characterizing the contemporary society. At the same time it should also be a school for the children who do not thrive in school today. This kind of pedagogy must be backed by physical facilities that are groundbreaking differently than what we have seen traditionally." *[Consultation Draft, 2010: p. 14]*

Ill. 3.55 Ørestad´s high school - flexibility through an open plan interior

Ill. 3.56 Flexibility through folding walls

Ill. 3.57 Flexibility through mobile and multifunctional furniture

3 FOCUS AREAS

Given the increased focus on differentiation in elementary schools this section will deal with learning flexibility, wellbeing and age differentiation, which are three of the major focus points in school architecture.

LEARNING FLEXIBILITY

Since a guiding principle for the elementary school is differentiated learning, there is need within to provide diversity in the teaching and learning environments. Pupils should be able to alternate between different forms of work and workrooms, and therefore it is essential that the school is designed with flexible space and rooms that can easily be used for different activities. The different activities do not have to happen simultaneously, but the rooms should easily allow alternation between several types of learning processes, such as individual work, class instruction, teamwork and project work. ["Model Program for public schools " 2010: p. 20]

HOME BASE

Home classrooms replace traditional classrooms, and can be described as the place the students have a real affinity for, and which also is associated with a permanent group of teachers.

They create a fixed point in the course of everyday life.

INTRODUCTION ROOM

Introduction rooms facilitate project work. The rooms' immediate task is to animate discussion and to provide the frames for smaller presentations of projects.

WORK STATION

Smaller work stations stem from the desire for differentiated teaching.

SUBJECT ROOMS

The traditional subject rooms have often been divided into well-defined subjects. Now a more interdisciplinary education with an open environment is sought.

SHARED AREA

A room that encourages the meeting with others. Community provides security and opportunity to interact with each others across class and age.

TEACHER ROOM

The teacher-pupil relationship has changed. The teachers are no longer hidden behind a pulpit. Instead they move around in class to help and discuss with the pupils. Therefore, they need a place to stay when the pupils are immersed in their work - a place that facilitates oversight and contact, and which functions as a contact point where the pupils at all times can turn.

RECREATIONAL SPACE

Not all rooms must be assigned a function. The pupils must also have the opportunity to put their stamp on the school.

STOREROOM

Because of the versatility of the classrooms, it is necessary to create space for storage of materials, props and the pupils semi-finished products.

HOT SPOTS

Social meeting spot

MEDIATHEQUE

Replaces the traditional school library and offers not only the loan of books but also the use of multimedia such as computers, video editing and the like. Furthermore, the Mediatheque must accommodate meetings, breaks and study areas.

Ill. 3.58 Diagram of different functions that the new school should contain to ensure differentiated learning

WELLBEING

Elementary school is the physical frame and perhaps the most important social community for Danish children for about 10 years of their lives. In recent years international researchers have found evidence for a close correlation between wellbeing, motivation and learning. To ensure the wellbeing of as many pupils as possible, the school must balance between space and activities that create a strong common culture. That can help create a positive identification and affiliation with the school. The common culture should also support the ability to establish smaller social communities within the large.

The school environments should be designed to respect and appreciate both individual differences and social interaction - ie. the children should be able to be together without being forced to. The rooms' design must provide the framework for and stimulate community formation. ["Tomorrow's buildings for children - space for play and learning" 2008: p. 14]

Recent research has demonstrated a close correlation between physical activity, wellbeing, concentration and learning. The school must contribute in giving the children and young people an understanding of the value of physical activity and in giving them good habits in that matter. The rooms and the spaciousness must support and stimulate movement and physical activity. ["Model Program for public schools " 2010: p. 21]

Ill. 3.59 and 3.60 Small spaces within the large

Ill. 3.61 Outdoor activities

"Activity and bodily expression is not to be restricted to scheduled activity hours in the day-care or kindergarten or to exercise classes in school, but must be incorporated in all aspects and activities, in architecture and in interior design. Exercise should be a natural option inherent in all of the normal activities during the day. We must focus on activity when we design spaces for learning."

["Tomorrow's buildings for children - space for play and learning" 2008: p. 21]

AGE DIFFERENTIATION

Children's individual needs change according to their stage of development. In 2008, Aarhus Municipality published a think tank report entitled "Tomorrow's buildings for children - space for play and learning. " Based on studies about the development of the brain and body the think tank outlines some spatial parameters that are consistent with children's respective development.

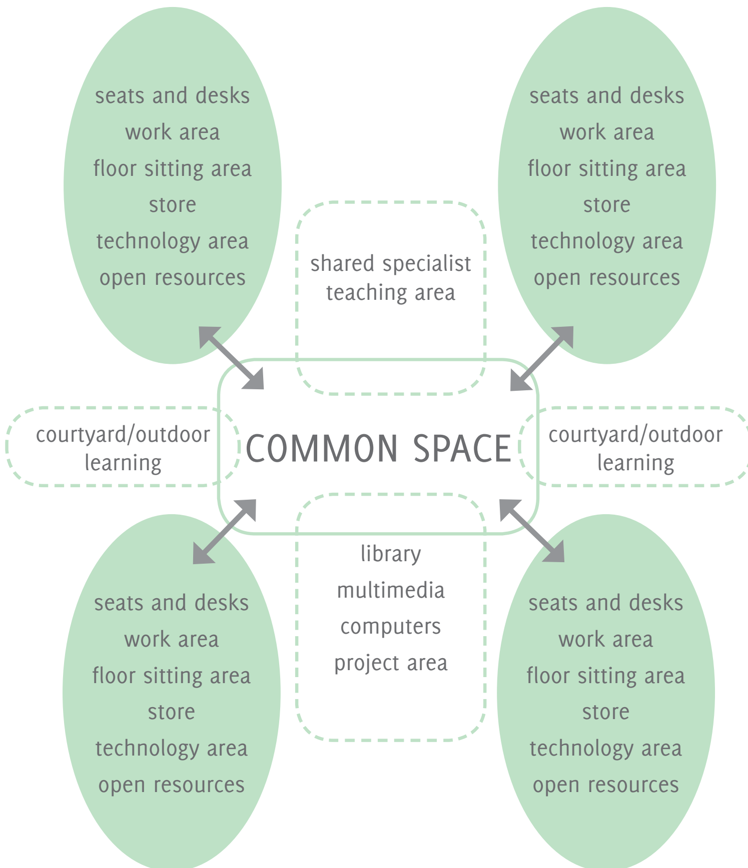
Space and interior decor must take into account that children develop much during their first 18 years of life and that different stages of development require different challenges. It is important to design schools so that children regularly face new challenges and are offered a changing environment along with their development. Brain maturation is crucial for children's approach to learning and it determines at what time one can expect that a given educational effort is worthwhile. ["Tomorrow's buildings for children - space for play and learning" 2008: p. 15]

The following pages describe three different stages of development – each with it's own demands for design and interior, based on the report "Tomorrow's buildings for children - space for play and learning".

"When we design rooms, it must be taken into account how space and rooms affect humans and how the orchestration and design of the room play with the child's current level of development."

["Tomorrow's buildings for children - space for play and learning" 2008: p. 15]

Ill. 3.62 Cebra - different activities to different age groups



Ill. 3.63 General structure for A kids

A: PRIMARY LEVEL (6-10 years)

Flexible interior
The rooms for the primary pupils must be very flexible. The design needs to enable space for all sizes of groups, ranging from three tracks together in a room to one class divided into small groups with removable walls or partitions, facilitating quiet contemplation. Also the furniture must be flexible such as folding tables etc.

Children are comfortable in rooms, which are not always designed for a specific function. Therefor transition zones should be established for example inbetween classrooms and between classrooms and the playground.

Reading rooms
There should be reading rooms with pillows and mattresses so that children can have reading weeks and bring their own pillows and cuddly toys and go to the library and find some easy-to-read books and then lie down or sit down and read - just like adults also prefer it when we are enjoying ourselves with a book!

Exterior
The playground is at least as important as it was at kindergarten age, only it is now also relevant with cabins in trees, climbing frames / walls, challenges, hideouts and fireplace.

Service functions
The area for the primary pupils must have a small kitchen available.

Educational effects
It must be taken into account that children at that age contemplate the world very concrete and operational. If they are to learn about animals or nature, then those should be within reach – to touch and to see. Therefore, books are just one type of learning tool for the youngest pupils. Other much more palpable effects are also needed. ["Tomorrow's buildings for children - space for play and learning." 2008: p. 26]

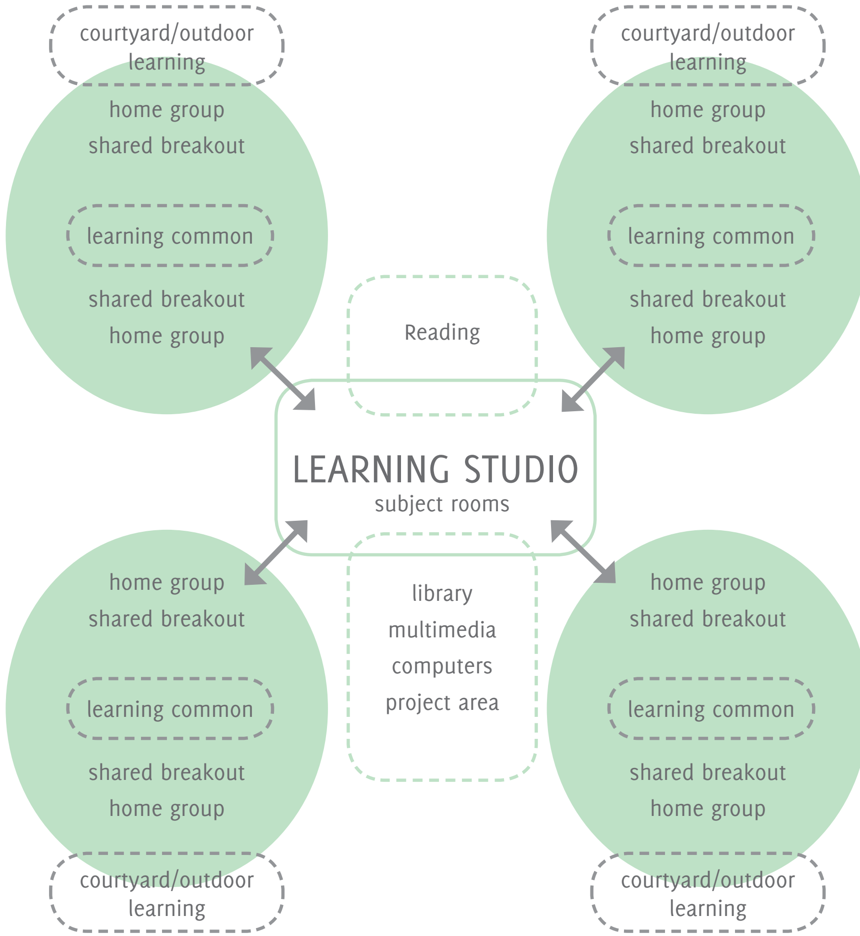
B: MIDDLE LEVEL (10-13 years)

Traditional teaching

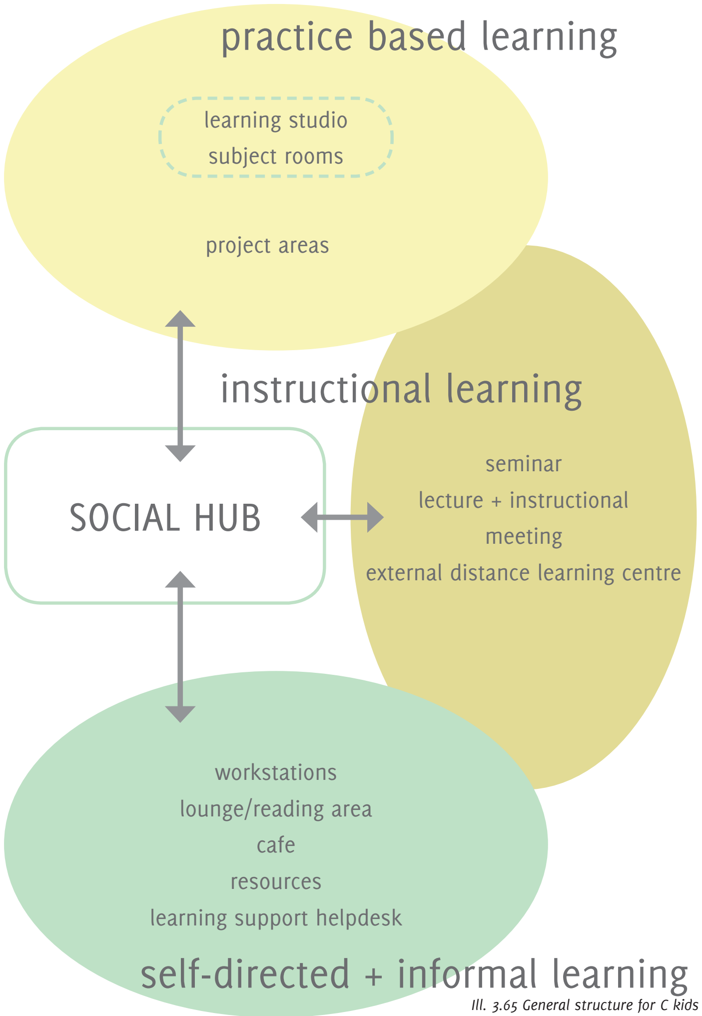
The middle school age is when children are most ready for the more traditional learning methods, fixed seating and permanent classrooms, although of course they can still benefit from other methods.

Strategic intelligence – for better or worse

Here the brain is capable of understanding relations. Some kids develop a strong strategic intelligence at this stage. The middle level is where teasing, bullying, being "inside" and "out " of the group really starts. Role play and acting can be tools to provide for indirect conversations about comradery, good environment in the classroom, accepted language, how to welcome new children, how to react to people being different from one self etc. ["Tomorrow's buildings for children - space for play and learning." 2008: p. 27]



Ill. 3.64 General structure for B kids



Ill. 3.65 General structure for C kids

FINAL LEVEL (14-16/17 years)

New surroundings
In the final level the pupils feel a resistance against the rooms that used to be important to them. They distance themselves from the rooms they know from "when they were young." Instead of being inside the classroom, they prefer to reside in the corridors or work in groups while sitting on the radiator instead of on a chair. Valuable learning may just as well take place on stairs, in corners, in hallways, in basements and lofts as in the traditional classrooms. Young people love the rooms and spaces for which they themselves have invented a function.

Teenagers' growth and hormones
Teenagers grow - and sometimes they grow a lot within very short time. That is why good quality chairs and tables that allow for flexible height has never been more important than now. The older pupils require plenty of air, large windows, which can be opened, fans or air conditioning etc. Teenagers with their raging hormones create a peculiar odor.

Smart boards
The smart board is a hit. It requires, however, decent curtains, so the smart board is visible even on sunny days.

Physical activity
When in their teens the pupils are still receptive of influences to their future choices and life habits. Therefore, facilities that allow for sports and physical activity cannot be overestimated. ["Tomorrow's buildings for children - space for play and learning." 2008: p. 28]

CASES

Case studies are used to evaluate how architectural solutions can support and perhaps even emphasize different educational values and principles.

Different features from the case studies has been used as inspiration and reinterpreted into the new design of the school.

Ill. 3.66 Lisbjerg: The central space in one cluster

Ill. 3.67 Lisbjerg: Central space of the whole school

SCHOOL OF LISBJERG

"HOME FEELING"

Architect: Kjaer & Richter
Year: 2008
Location: Lisbjerg, Denmark

The school was built with such keywords as feeling of home, comfort, healthy indoor environment in mind. These keywords are intended to apply to our project as well.

The building is divided into smaller units and combined into one whole by the central area – the atrium. The atrium serves as canteen and library on the first and second levels. Other units include classrooms for differently aged children, administration corpus, subject rooms, new parish community centre, which serves as a gathering point for the Lisbjerg community.

Each unit of classrooms is organized around the central stairs that serves as a gathering place. The good daylight conditions are guaranteed by placing a north-oriented skylight.

EGÅ HIGH SCHOOL

"DIVERSITY"

Architect: Cubo
Year: 2006
Location: Aarhus, Denmark

The high school is formed like a white two-storey island in the landscape.

The classrooms are placed around the perimeter of the school and surround the central circle-shaped space. The space is divided into canteen and the forum – main knowledge space. Special subject rooms are found there.

Long narrow corridors are eliminated; instead the circular movement is organized. In this case almost every square meter of transition spaces can be used as a place for studying. Such spaces contains glass cabins for group work, spaces with soft bean-bags for relaxing and working, movable blackboards that can be arranged anywhere and anyhow depending on the needs of students.

Ill. 3.68 Egå: Informal space both for studying and relaxing

Ill. 3.69 Egå: Canteen

Ill. 3.70 Egå: The forum - subject room core

FUJI KINDERGARTEN

"PLAY AND MOVEMENT"
Architect: Tezuka Architects
Year: 2007
Location: Tokyo, Japan

Fuji kindergarten is a good example of how inside and outside spaces merge together into one. The building is transparent and visible to all. The building incorporates 3 existing trees and makes them a part of the learning environment.

The oval form creates a sharp edge from the outside, and a safe inner courtyard inside. Accessibility to the roof, stairs and climbing nets encourages movement.

The other interesting feature is the use of special timber boxes. Three types of sizes were made for different age groups. They can be used for sitting, as desks, for display, storage, they can be stocked and form a partition.

GREEN SCHOOL

"NATURE AND KNOWLEDGE"
Architect: Kieran Timberlake
Year: 2006
Location: Washington DC, USA

Sidwell Friends School is a interesting example on how nature can be integrated into the school's curriculum.

The inner courtyard consists of the terraced wetland which not only provides a rich wildlife, but also treats schools waste water and is an educational resource. Children can observe the water treatment mechanisms, flora and fauna and use the knowledge for the classes.

Schools roof is covered with grass and contains small vegetable and a herbs garden. The harvest is later used in the school's canteen. [imagineschooldesign.org]

Ill. 3.71 Green school: The wetland at Sidwell Friends School

Ill. 3.72 Fuji: Birds-eye view of kindergarten

INITIAL ROOM PROGRAM

The initial room program is established for 850 students and 50 staff. The program is created following Aarhus municipality recommendations and after a trip to the school of N.J. Fjordsgade. The new school should provide space for 3 different age-groups of children: grades 0 to 3, grades 4 to 6 and grades 7 to 9. Appropriate amount of rooms for teachers, administration and other staff needs to be designed accordingly.

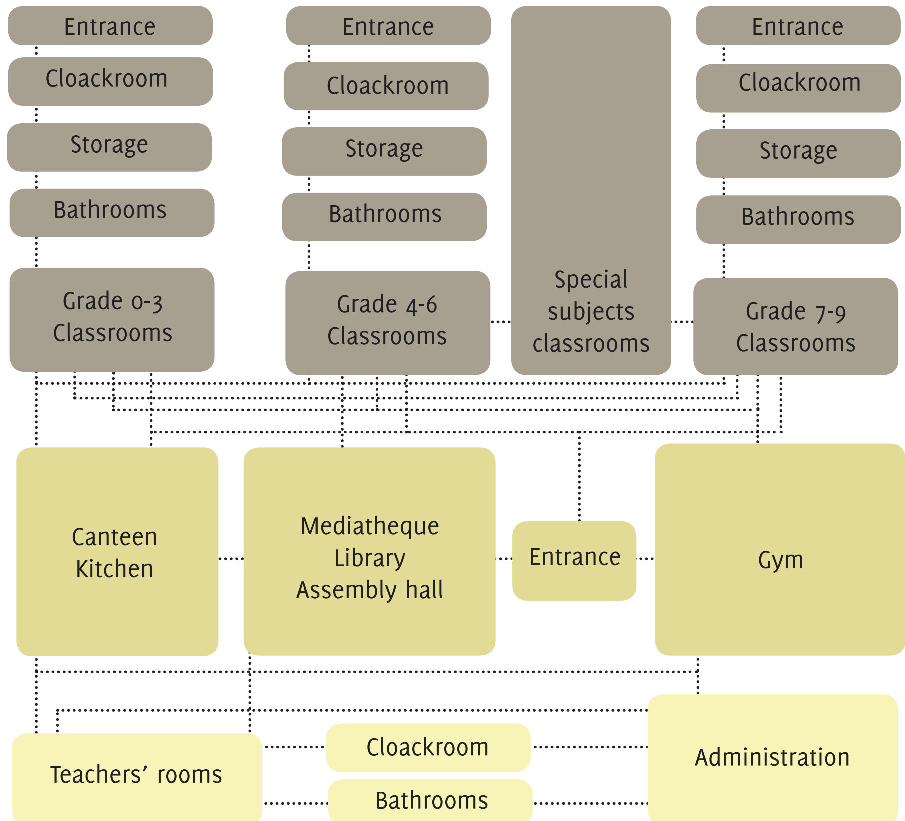
The initial room program is based on similar projects such as; "Vibeengskolen" from 2010 by Arkitema and "Tjørring skole" from 2009 by Friis & Moltke.

The diagram 3.74 on the next page illustrates the relationship between different spaces in the school and shows how they interact with each other.

NAME OF ROOM	NUMBER OF ROOMS	AREA, m2	AMOUNT OF PEOPLE	ROOM HEIGHT,m	ROOM VOLUME,m3	ZONING
DISTRICT						
Classroom [grade 0-3]	12	80	Max 30*	3,5	280	Private
Classroom [grade 4-6]	9	60	Max 29*	3,5	210	Private
Classroom [grade 7-9]	9	60	Max 29*	3,5	210	Private
Shared areas *(meeting, working)*	3	500	Max 260	3,5	1750	Private
Toilets	3	50	Max 12	3,5	175	Private
Wardrobe	3	150	Max 80	3,5	525	Private
SUBJECT ROOMS						
Visual arts	1	85	Max 29	3,5	297,5	Private
Music	1	85	Max 29	3,5	297,5	Private
Woodwork	1	100	Max 29	3,5	350	Private
Crafts	1	100	Max 29	3,5	350	Private
Home economics	1	100	Max 29	3,5	350	Private
Physics/Chemistry	1	100	Max 29	3,5	350	Private
Biology/Geography	1	100	Max 29	3,5	350	Private
Mathematics	1	85	Max 29	3,5	297,5	Private
IT	1	85	Max 29	3,5	297,5	Private
PUBLIC FUNCTIONS						
Sports hall	1	700	Max 56	6	4200	Semi-Private
Fitness	1	100	Max 20	3,5	350	Semi-Private
Changing rooms (teachers)	1	90	Max 20	3,5	315	Semi-Private
Changing rooms (pupils)	1	180	Max 56	3,5	630	Private
Canteen	1	440	Max 300	7	3080	Semi-Private
Kitchen	1	100	Max 3	3,5	350	Private
Library	1	400	Max 300	7	2800	Semi-Private
Auditorium	1	320	Max 280	5	1600	Semi-Private
Entrance	1	430	Max 300	3,5	1505	Semi-Private
Handicaped WC	3	4	Max 1	3,5	14	Semi-Private
ADMINISTRATION						
Offices	6	18	Max 6	3,5	63	Private
Staff room	1	100	Max 25	3,5	350	Private
Preparation room	1	95	Max 25	3,5	332,5	Private
Wardrobe	1	20	Max 10	3,5	70	Private
Nurse	1	15	Max 2	3,5	52,5	Private
Kitchen	1	15	Max 2	3,5	52,5	Private
Toilets	4	1,5	1	3,5	5,3	Private
Printer	1	10	1	3,5	35	Private
Technical rooms	3	20	1	3,5	70	Private
Storage	3	10	1		35	Private

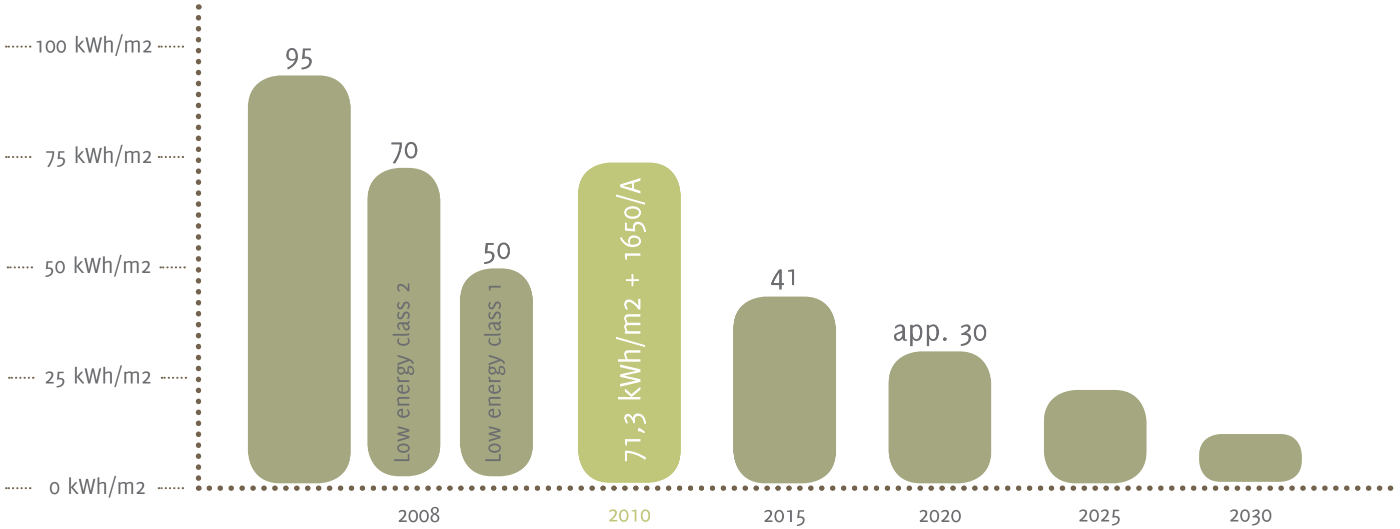
Max 30 - 28 students and 2 pedagogs*
*Max 29 * - 28 students and 1 teacher*

Ill. 3.73 Initial room program



Ill. 3.74 Relationship between the functions

REQUIREMENTS
ENERGY



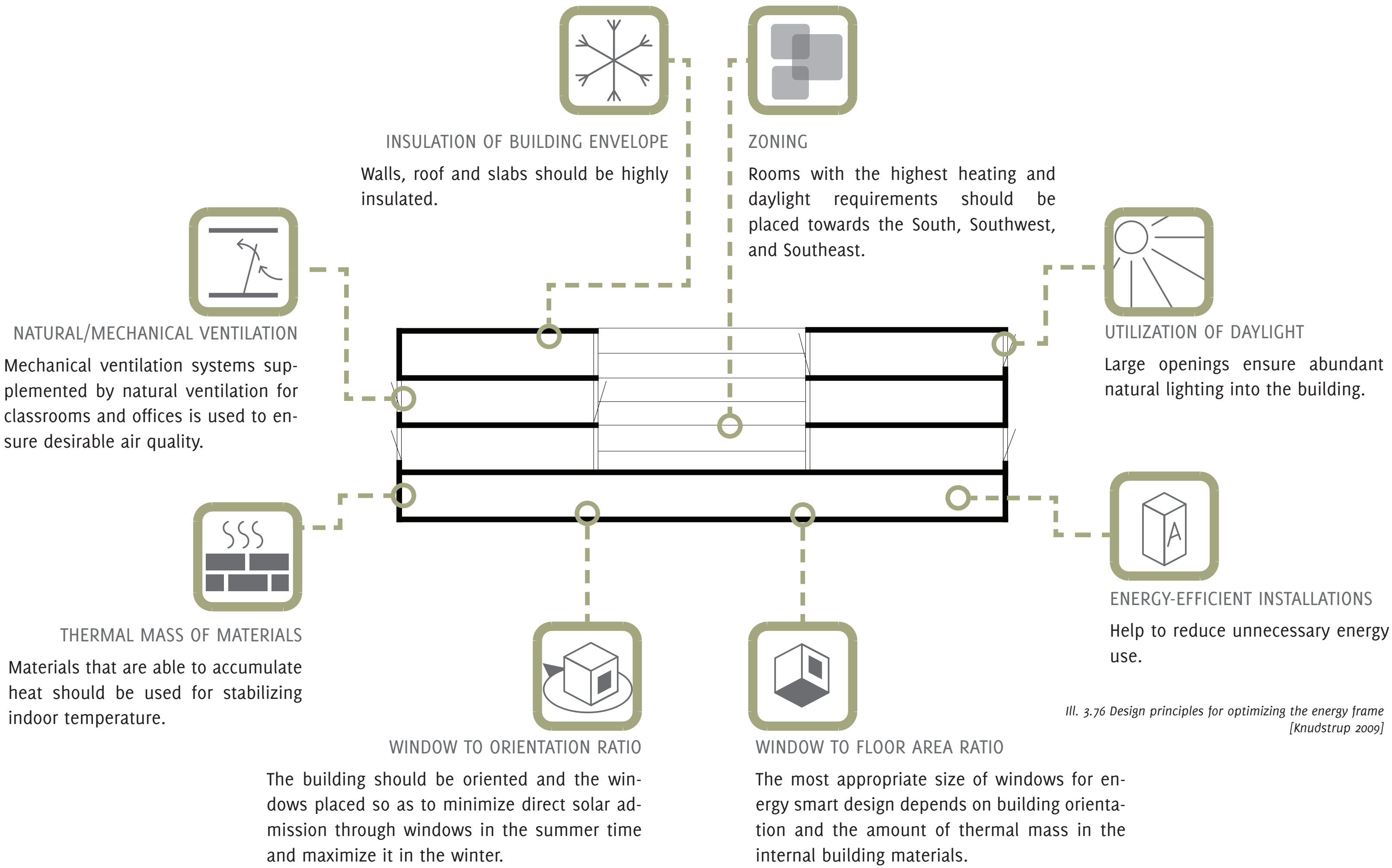
Ill. 3.75 Energy frame for schools, offices, institutions [Ramboll 2010]

BR10

In order to fulfill the requirements for the energy consumption frame, the Danish Building Regulations 2010 (BR10) will be followed. The diagram above gives an overview of how energy demands for schools, offices and other public institutions have been changing recently. A tendency of reducing primary energy demands by 25% every 5 years is evident.

In 2010 there has been a tightening of the building regulations, where the current energy frame has become equivalent to the previous low energy class II. In order to comply with the new requirements various concerns on lowering energy consumption must be taken into account.

Design guidelines related to these concerns are shown in the illustration on the following page.



Ill. 3.76 Design principles for optimizing the energy frame [Knudstrup 2009]

INDOOR CLIMATE

INTRODUCTION

Over the last few decades, considerable attention has been directed towards the problems of indoor air quality in schools. It has become increasingly clear that exposure to contaminated indoor air may not only be unpleasant, but can have serious negative health effects.

Children of today spend increasingly more of their time in school environment. Because children breathe a greater volume of air relative to their body weight compared to adults, they may be more sensitive to indoor air pollution. ["Demand-based ventilation in schools": p.1-3]

New studies carried out in an elementary school in Denmark investigated whether indoor environment quality can affect the performance of schoolwork by children. The effects of increased outdoor air supply rates and reduced air temperatures in classrooms was investigated on the performance of schoolwork. They were carried out in classrooms with in total about 100 10-12-year old pupils.
The room temperature was reduced from 25 C to 20 C and the outdoor air supply rate was increased from 5,2 to 9,6 L/s per person. The results suggest that higher ventilation rates up to 10 L/s per person as well as more strict temperature control than commonly used can be recommended for classrooms. This means that careful selection of air distribution solutions must be made in order to avoid draft and unhealthy indoor environment.

The results were evident, reduced temperature significantly increased the rate at which pupils subtracted numbers and performed a reading and comprehension task. Increased outdoor air supply rate significantly improved the performance of individual tasks by from 3% to 35%. [http://www.iciee.byg.dtu.dk]

The focus of this project is to design a school building in an integrated way, where good building physics in combination with smart building systems fulfills the requirements for category A for indoor environment quality.

The structural part of the indoor climate covers thermal conditions, air quality, acoustic indoor climate and light conditions. For air quality as well as both thermal and light conditions specific design criterias have to be fulfilled. The acoustic indoor climate is only described.

DAYLIGHT

Good daylight conditions have a proven positive effect on the learning abilities of children. Therefore when designing a school, some strategies should be taken in consideration, such as high-ceilinged rooms which provide better utilisation of daylight as well as the colours of the rooms - especially of the window frames - which have a great influence. Light colours help to reduce glare around the windows. In order to support daylighting, artificial lighting should be adjustable to varying activities. ["Sunde skoler" 2001: p.23]

Windows must be made, located and, where appropriate, screened in a way so that sunlight through them does not cause overheating in the rooms, and direct solar heat gain is avoided. [BR10 6.5>SBi 230]

In order to enable people to perform visual tasks efficiently and accurately, adequate light without side effects like glare and blinding) must be provided. [DS/EN 15251]

Evaluation of light conditions must be seen in relation to the specific function in a room and in this project this is described in ill. 3.77 where according to DS/EN 15251 the specific demands of all rooms are shown.

NAME OF ROOM	DAYLIGHT TYPE	LIGHT INTENSITY, lux
DISTRICT		
Classroom [grade 0-3]	Natural	200
Classroom [grade 4-6]	Natural	200
Classroom [grade 7-9]	Natural	200
Shared areas *(meeting, working)*	Natural	200
Toilets	Artificial	200
Wardrobe	Artificial	200
SUBJECT ROOMS		
Visual arts	Natural	200
Music	Natural	200
Woodwork	Natural	200
Crafts	Natural	200
Home economics	Natural	200
Physics/Chemistry	Natural	200
Biology/Geography	Natural	200
Mathematics	Natural	200
IT	Natural	200
PUBLIC FUNCTIONS		
Sports hall	Natural	200
Fitness	Natural	200
Changing rooms (teachers)	Natural/Artificial	200
Changing rooms (pupils)	Natural/Artificial	200
Canteen	Natural	200
Kitchen	Natural/Artificial	200
Library	Natural	200
Auditorium	Natural/Artificial	500
Entrance	Natural	200
Handicaped WC	Artificial	100
ADMINISTRATION		
Offices	Natural	200
Staff room	Natural	200
Preparation room	Natural	200
Wardrobe	Artificial	100
Nurse	Natural	200
Kitchen	Natural/Artificial	200
Toilets	Artificial	100
Printer	Artificial	200
Technical rooms	Artificial	-
Storage	Artificial	-

Ill. 3.77 Light types and intensity

THERMAL INDOOR CLIMATE

TYPE OF ROOM	AREA, m2	ROOM HEIGHT,m	ROOM VOLUME,m3	MAX PEOPLE LOAD	ACTIVITY LEVEL,met	CLOTHING, SUMMER/ WINTER, clo	INTERNAL HEAT LOADS: HEAT EMISSION, PERSON, W	INTERNAL HEAT LOADS: EQUIPMENT+LIGHT/ W/m2	OPTIMAL OPERATIVE TEMPERATURES: SUMMER, C	OPTIMAL OPERATIVE TEMPERATURES: WINTER, C
DISTRICT										
Classroom [grade 0-3]	80	3,5	280	0,375	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Classroom [grade 4-6/7-9]	60	3,5	210	0,48	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Shared areas *(meeting, working)*	500	3,5	1750	0,5	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Toilets	50	3,5	175	0,24	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Wardrobe	150	3,5	525	0,5	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
SUBJECT ROOMS										
Subject room	85	3,5	297,5	0,34	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
PUBLIC FUNCTIONS										
Sports hall	700	6	4200	0,08	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Fitness	100	3,5	350	0,2	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Changing rooms (teachers)	90	3,5	315	0,22	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Changing rooms (pupils)	180	3,5	630	0,31	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Canteen	440	7	3080	0,68	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Kitchen	100	3,5	350	0,03	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Library	400	7	2800	0,75	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Auditorium	320	5	1600	0,875	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
Entrance	430	3,5	1505	0,69	1,2	0,5/1	54	4	23,5-25,5	21,0-23,0
ADMINISTRATION										
Offices	18	3,5	63	0,33	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Staff room	100	3,5	350	0,25	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Preparation room	95	3,5	332,5	0,26	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Wardrobe	20	3,5	70	0,5	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Nurse	15	3,5	52,5	0,13	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Printer	10	3,5	35	0,2	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0
Technical rooms	20	3,5	70	0,5	1,2	0,5/1	90	4	23,5-25,5	21,0-23,0

Ill. 3.78 Design criteria due to thermal indoor climate

THERMAL COMFORT

Thermal indoor climate concerns characteristics of the indoor environment which affect the heat exchange between the human body and the environment. The aim is to obtain thermal comfort, which is measured as satisfaction with the thermal environment. [BR 10 6.2]

There is good evidence that moderate changes in room temperature affect children's abilities to perform mental tasks requiring concentration. However, while warmer temperatures tend to reduce performance, colder temperatures reduce manual dexterity and speed. Hence the need to avoid extreme conditions and to provide for as much individual temperature control as possible is strongly recommended. ["IAQ and student performance"]

As described above, temperature in the rooms should meet the limits of optimal operative temperatures. Furthermore, category A allows a permissible vertical air temperature difference of <2 C°. [CR1752, A.2]

In order to avoid overheating solar shading may be considered as an option, yet it must not obstruct the views and light, and interfere with architectural expression. ["Sunde skoler" 2001: p.23]

HUMIDITY

Humidity has only a small effect on thermal sensation and perceived air quality in the rooms of sedentary occupancy, however,· long term high humidity indoors will cause microbial growth, and very low humidity, causes dryness and irritation of eyes and air ways.
Recommended humidity level for category A building should be kept between 30-50%. [DSEN 15251, B.6]

ATMOSFERIC INDOOR CLIMATE				SENSORY POLLUTION LOADS			POLLUTANTS, CO2	
TYPE OF ROOM	AREA, m2	ROOM HEIGHT,m	ROOM VOLUME,m3	MAX PEOPLE LOAD	ACTIVITY LEVEL,met	BUILDING, low-polluting, olf	PEOPLE, olf	CO2 from persons, l/h
DISTRICT								
Classroom [grade 0-3]	80	3,5	280	0,375	1,2	0,8	1,3	383,5
Classroom [grade 4-6/7-9]	60	3,5	210	0,48	1,2	0,6	1,3	363,1
Shared areas *(meeting, working)*	500	3,5	1750	0,5	1,2	5	1,3	3182,4
Toilets	50	3,5	175	0,24	1,2	0,5	1,3	146,8
Wardrobe	150	3,5	525	0,5	1,2	1,5	1,3	979,2
SUBJECT ROOMS								
Subject room	85	3,5	297,5	0,34	1,2	0,85	1,3	375,3
PUBLIC FUNCTIONS								
Sports hall	700	6	4200	0,08	1,2	70	1	5752,8
Fitness	100	3,5	350	0,2	1,2	10	1	2040
Changing rooms (teachers)	90	3,5	315	0,22	1,2	0,9	1,3	408
Changing rooms (pupils)	180	3,5	630	0,31	1,2	1,8	1,3	685,4
Canteen	440	7	3080	0,68	1,2	4,4	1	3672
Kitchen	100	3,5	350	0,03	1,2	10	1,3	61,2
Library	400	7	2800	0,75	1,2	40	1,3	3672
Auditorium	320	5	1600	0,875	1,2	32	1,3	3468
Entrance	430	3,5	1505	0,69	1,2	43	1,3	3672
ADMINISTRATION								
Offices	18	3,5	63	0,33	1,2	0,18	1	122,4
Staff room	100	3,5	350	0,25	1,2	10	1	510
Preparation room	95	3,5	332,5	0,26	1,2	0,95	1	510
Wardrobe	20	3,5	70	0,5	1,2	0,2	1	204
Nurse	15	3,5	52,5	0,13	1,2	0,15	1	32,6
Printer	10	3,5	35	0,2	1,2	0,1	1	40,8
Technical rooms	20	3,5	70	0,5	1,2	0,2	1	20,4

Ill. 3.79 Pollution sources

INDOOR AIR QUALITY

BR10 6.3> CR1752> DS/EN 15251
The requirements for the air quality in a room are first that the health risk of breathing the air should be negligible and second that the air should be perceived to be fresh and pleasant.

The atmospheric indoor climate is concerned with components in the air that affect the human body. In general it is a matter of the experienced air quality in proportion to pollution.

Analysis of extensive studies from all over the world show that main problems related to indoor air quality in schools are: insufficient fresh air supply leading to high CO_2 concentrations, problems related to emissions from building materials as well as problems related to outdoor air pollution problems. ["Indoor climate and ventilation of schools" 2007: p.2-4]
Thus, a careful choice of ventilation strategy must be made.

When designing for category A, in regards to CR1752 there are some general design criterias:
› 15% dissatisfied due to perceived air quality when pollution in air is 1,0 decipol (A.5);
› 0,1 decipol in perceived outdoor air quality (A.9);
› 350 ppm CO_2 in outdoor level of air when designing in town with good air (A.9);
› 460 ppm CO_2 above outdoor level of air quality (A.3.3.3);
› 0,1 olf/m2 of pollution from the building (A.8);
› 1,3 olf of pollution from person (A.6);
› smoking is not permitted;

In this project, the limit of 810ppm CO_2 in perceived indoor air quality is allowed.

VENTILATION

							INTERNAL HEAT LOADS		OPTIMAL OPERATIVE TEMPERATURES		
TYPE OF ROOM	AREA, m2	ROOM HEIGHT,m	ROOM VOLUME,m3	MAX PEOPLE LOAD	ACTIVITY LEVEL,met	VENTILATION RATE (temperature), l/s	AIRCHANGE (temperature), h^{-1}	VENTILATION RATE (sensory pollution), l/s	AIRCHANGE (sensory pollution), h^{-1}	VENTILATION RATE (based on CO_2), l/s	AIRCHANGE (based on CO_2), h^{-1}
DISTRICT											
Classroom [grade 0-3]	80	3,5	280	0,375	1,2	107	3,31	522	6,71	106	2,98
Classroom [grade 4-6/7-9]	60	3,5	210	0,48	1,2	101	4,18	482	8,27	100	3,76
Shared areas *(meeting, working)*	500	3,5	1750	0,5	1,2	596	2,95	4166	8,57	884	3,95
Toilets	50	3,5	175	0,24	1,2	27	1,36	228	4,71	40	1,82
Wardrobe	150	3,5	525	0,5	1,2	159	2,63	1250	8,57	272	4,05
SUBJECT ROOMS											
Subject room	85	3,5	297,5	0,34	1,2	117	3,43	511	6,19	104	2,74
PUBLIC FUNCTIONS											
Sports hall	700	6	4200	0,08	1,2	245	0,51	7000	6,00	1598	2,98
Fitness	100	3,5	350	0,2	1,2	101	2,50	2333	24,00	566	12,67
Changing rooms (teachers)	90	3,5	315	0,22	1,2	86	2,38	320	3,66	113	2,82
Changing rooms (pupils)	180	3,5	630	0,31	1,2	147	2,03	1006	5,75	190	2,37
Canteen	440	7	3080	0,68	1,2	1473	4,14	4810	5,62	1020	2,59
Kitchen	100	3,5	350	0,03	1,2	70	1,73	144	1,49	17	0,38
Library	400	7	2800	0,75	1,2	1718	5,31	4777	6,14	1020	2,85
Auditorium	320	5	1600	0,875	1,2	587	3,18	4400	9,90	963	4,71
Entrance	430	3,5	1505	0,69	1,2	953	5,48	4763	11,39	1020	5,30
ADMINISTRATION											
Offices	18	3,5	63	0,33	1,2	24	3,31	86	4,91	34	4,22
Staff room	100	3,5	350	0,25	1,2	186	4,62	389	4,00	141	3,17
Preparation room	95	3,5	332,5	0,26	1,2	186	4,85	380	4,11	141	3,33
Wardrobe	20	3,5	70	0,5	1,2	38	4,80	133	6,86	56	6,34
Nurse	15	3,5	52,5	0,13	1,2	14	2,39	38	2,63	9	1,35
Printer	10	3,5	35	0,2	1,2	16	4,08	33	3,43	11	2,53
Technical rooms	20	3,5	70	0,5	1,2	22	2,76	33	1,71	5	0,63

Ill. 3.80 Required ventilation rates

VENTILATION ACCORDING TO ACTIVITIES

Indoor environment problems are often caused by changed use of the building, changed teaching methods, changed physical behaviour of the pupils inside the building and inadequate building maintenance. "Open school concepts" that lead to pupils moving around in classrooms and working part-time in the hallways affects school design and therefore school HVAC system design.

Another issue is very often that schools are becoming more and more public by providing a public access to sports facilities, course centres or evening clubs with activities around the clock and throughout the year. Therefore, due to large variations in demand, there is a need of a ventilation system which enables demand-based control. Airflow control should be possible within very wide parameters so that differences in the size of the group can be managed energy-economically. In a standard class, the possibility should be allowed of increasing airflow by 20% so that larger teaching groups can also be catered for. ["Demand-based ventilation in schools": p.1-3]

Acoording to Building regulations 2010, hybrid or mechanical ventilation should be used in schools except for offices, which can be ventilated by natural ventilation.

Teaching rooms in schools must be ventilated by ventilation installations comprising forced air supply and exhaust. Fresh air supply to and extraction from normal teaching rooms must be no less than 5 l/s/person plus 0,4 l/s/m2 floor area. [BR10 6.3]

Above a table is to show different needs for comfort demands, airchanges and ventilation rates according to rooms usage.

DESIGN CRITERIA

CONTEXTUAL APPROACH

Traditional urban structure with streets and courtyards
The building must relate to the community and the city structure, and invite the city into the area.

Skolemarken and skatepark
Improve and strengthen the area's existing qualities in relation to the local area.

24/7/365
Add new possible uses to enrich the local area.

PEDAGOGICAL AND ARCHITECTURAL APPROACH

Flexibility and age differentiation
The school building must support learning flexibility and age differentiation as pedagogical principles and contain various learning environments to enhance pupils' individual learning needs and development.

Wellbeing
Enhance the sense of wellbeing and community feeling through variation of spaces and activities

Physical activity
Organization of the rooms and outdoor areas must support and stimulate movement and physical activity

Identity
The outer expression of the school building should reflect life inside the building

Identification and homeliness
Create transparency for users, so they can more easily navigate despite the vast size of the school

CLIMATE TECHNICAL APPROACH

Indoor climate
Ensure comfortable and healthy indoor climate by creating good air quality, acceptable temperature and CO_2 level

Daylight
Ensure good daylight quality in especially workareas such as classrooms, grouprooms, offices etc.

Energy
Energy frame should meet the standards from BR10.

VISION

The vision of this project is to design a new and modern school, which facilitates future-oriented educational principles in the center of Aarhus city.

The pedagogical focus areas are learning flexibility, well-being and age differentiation, which will be reflected into the architecture of the school and its surroundings.

A healthy indoor climate promotes the performance of schoolwork by children and must also be integrated into the building design.

The future school should encourage healthy lifestyle and conscious approach to the nature and city surroundings. The goal is to create synergy between pedagogical, architectonical and technical strategies.

SKETCHING

ORGANIZATION CONCEPT

CITY SCHOOL - SCHOOL AS A CITY

While developing the concept an inspiration from a city structure was taken. School community is as complex as urban community and parallels between those two can be easily noticed. For example “connections” like classroom = house, corridors = streets, gathering place = city square, green areas = city parks can be made.

A HOUSE

The most basic unit of the school is a classroom. It’s a home base for each group of the pupils, a starting point of the day, where the instructions for the rest of the day are received. The classroom should encourage a feeling of home and security.

NEIGHBORHOOD

Classrooms are arranged in groups of three to form a neighborhood. These neighborhoods share a certain connectedness and feeling of being together and is are parallel to a real city neighborhood. Children within neighborhoods are in the same age group, they have a lot in common and are able to benefit and learn from each other.

DISTRICT

All classrooms for each group of students (A, B or C) make a district. This is a complex structure containing houses (classrooms), squares (shared areas) and a garden (terrace). Each district is a good training ground for developing social skills. Different ages mix together giving a richer and more complex social pattern in which everyone has to find their niche as best as they can, and learn to function as one of many without being dominant or ignored .

All three districts are considered as private, since only students and the staff enter and use it.

PUBLIC CENTER

A tribute to the city is a public building, that includes canteen, auditorium, library, administration, sports facilities. The residents and guests of the area can use the above mentioned facilities after classes are over and in the weekends.

LEARNING STREET

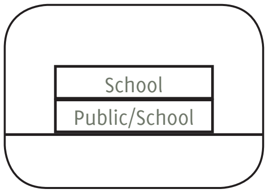
The learning street becomes a binding element for districts and public spaces.

It consists of subject rooms, such as science rooms (physics, chemistry, biology) , creative rooms (arts, music, theater) and culture classrooms (geography, history). The learning street is a main artery that runs through and connect the whole building.

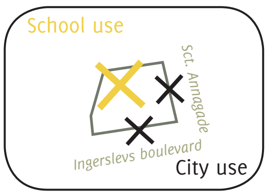
Ill. 4.1 Functional diagram

URBAN
FUNCTIONS AND CONNECTIONS

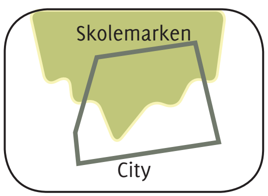
STRATEGIES



Ill. 4.2 Zoning vertical



Ill. 4.3 Activities



Ill. 4.4 Urban and Green connection

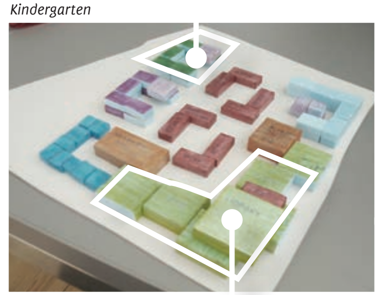
URBAN SPACE

Located centrally in the city the school must relate to the surrounding urban activities and add new uses to enrich the local area. Public functions are placed on the ground floor to make them easily accesible and useful for other purposes and at different times of day. By integrating public functions such as sports facilities, food court/cafe and theater/music stage the school will serve as a gathering place for local residents and users and not go to "sleep" after classes and 'after-school-care' (SFO) is over.

The green public field, Skolemarken, is a green oasis and is preserved and extended onto the site, which is then divided into a green and an urban space. The more urban character is oriented towards St. Annagade and Ingerslevs Boulevard where the site meets the city's ambience and scale. Towards Skolemarken the site is more characterized by openness and nature.

The sketching phase began with preparing different colored foam squares each symbolizing different functions of the school. Many different organization proposals were created and some of them pointed out for further development.

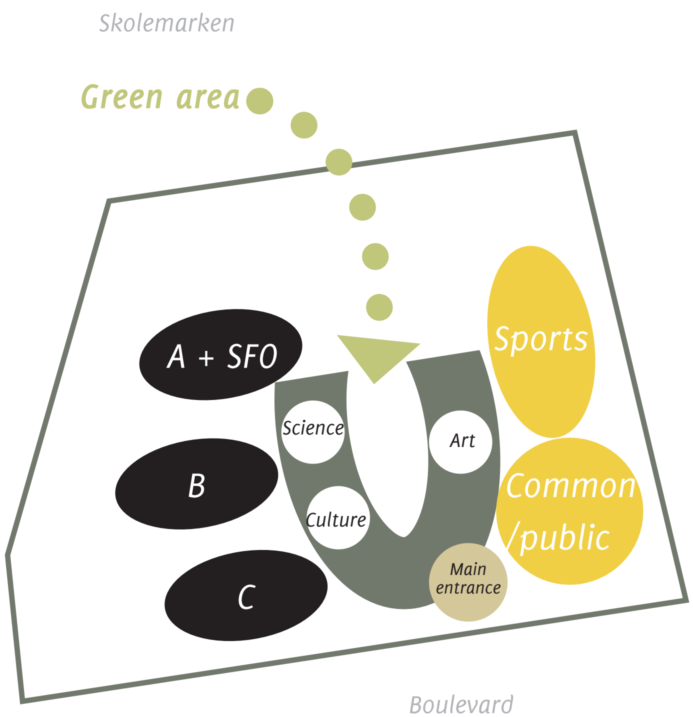
District A (0-3 grade) placed near Skolemarken and Kindergarten



Public functions placed near the street

Inner green courtyard connected with the Learning Street

Ill. 4.5 Model pictures



Ill. 4.6 Organisation diagram

THE SCHOOL

Inside the building a key focal point is to create an orderly building, which despite its size is easy to navigate in. The three stages both primary school (A + SFO), middle school (B) and final school (C) are distributed into districts to create clarity and affinity.

The smallest pupils in primary school (A) are placed closest to Skolemarken. Here they are close to nature and in a more guarded and protected area - away from the dangers of the world.

The oldest pupils in final school (C) are placed closest to the city. They are ready for the world, or at least they soon have to be. They are also more interested in the world outside school.

Pupils in middle school (B) are positioned as an intermediary and a transition between primary school and final school. The pupils here will have acces to both the completely safe environment and for the open outside world.

The arrival at the project site would primarily be via the large boulevard. The aim here is a primary flow that leads all visitors to the common center of the building. From here a visual link to the various features of the building makes it easy to orientate.

The various special subject rooms are gathered and divided into core areas to increase opportunities for collaboration across subject groups. The aim is also to create a close contact with the outdoor environment to extend teaching and work premises.

CITY STRUCTURE AND SCHOOL FORM

As part of the iterative design proces focus was also on the design of the school's outer form and its connection to the context.

The three school typologies; the multiple floor school, the function-segregated school and the spatial-flexible school were included early in the design process. The original basis forms were placed on the project site and then transformed and moulded to relate to the context, e.g. by following the urban linear and introverted bloc structure along Sct. Annagade and Ingerslevs Boulevard.

The forms were further processed and manipulated by optimizing them in terms of scale, flow, orientation, daylight conditions, openess/closedness and the quality of outdoor areas in terms of wind, sun and accessibility.

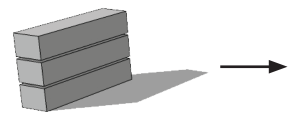
Various experiments were made with the corner of Sct. Annagade and Ingerslevs Boulevard in order to highlight it in different ways. This can be done by adding extra height or by the absence of volume, i.e. by pulling the building away and create an open space. By dissolving the simple and compact form it is sought to create a more inviting form and to allow more and readily available outdoor area.

By subtracting parts of the building from the street, the urban space is invited onto the site and the building no longer appears closed and repellent.

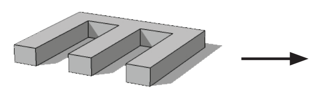
Focus has also been on creating exciting and varying outdoor environments which strongly relate to the areas inside the building - especially to the classrooms that must be in close contact with the outdoor areas in order to allow easy acces for the pupils during breaks or as part of the teaching.

After evaluating the various experiments, three form concepts - each based on one of the original typologies - are chosen to further evaluation.

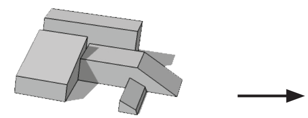
SCHOOL TYPOLOGIES



Multiple floor school



Function-segregated school

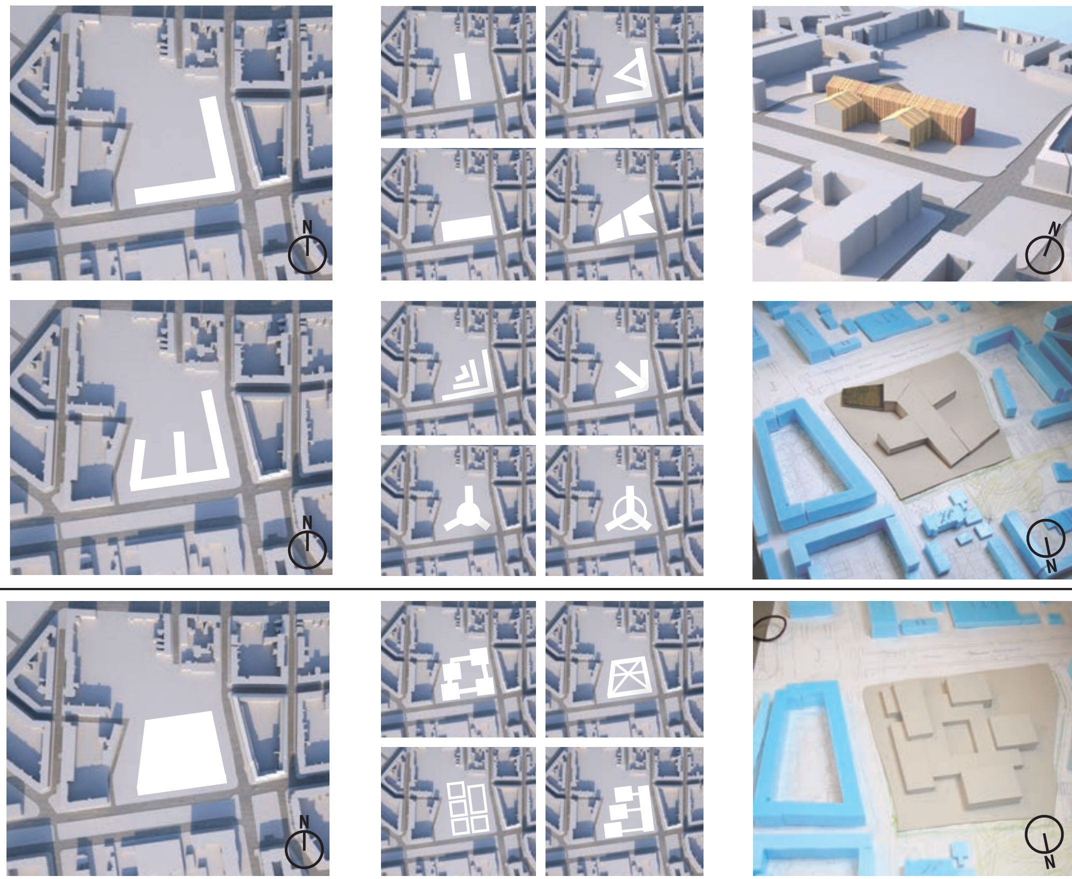


Spatial-flexible school

PHASE 1 - TYPOLOGIES ON SITE

PHASE 2 - FORM VARIATIONS

PHASE 3 - FORM CONCEPTS



+ *Scale fit to context*
+ *Linear expression - relates to exixsting axes*
+ *Adapt surrounding style (sloped roof)*
+ *Compact*

- *Does not take advantage of site*
- *Introvert*
- *Limits contact to outdoor areas*
- *Restricted daylight conditions*

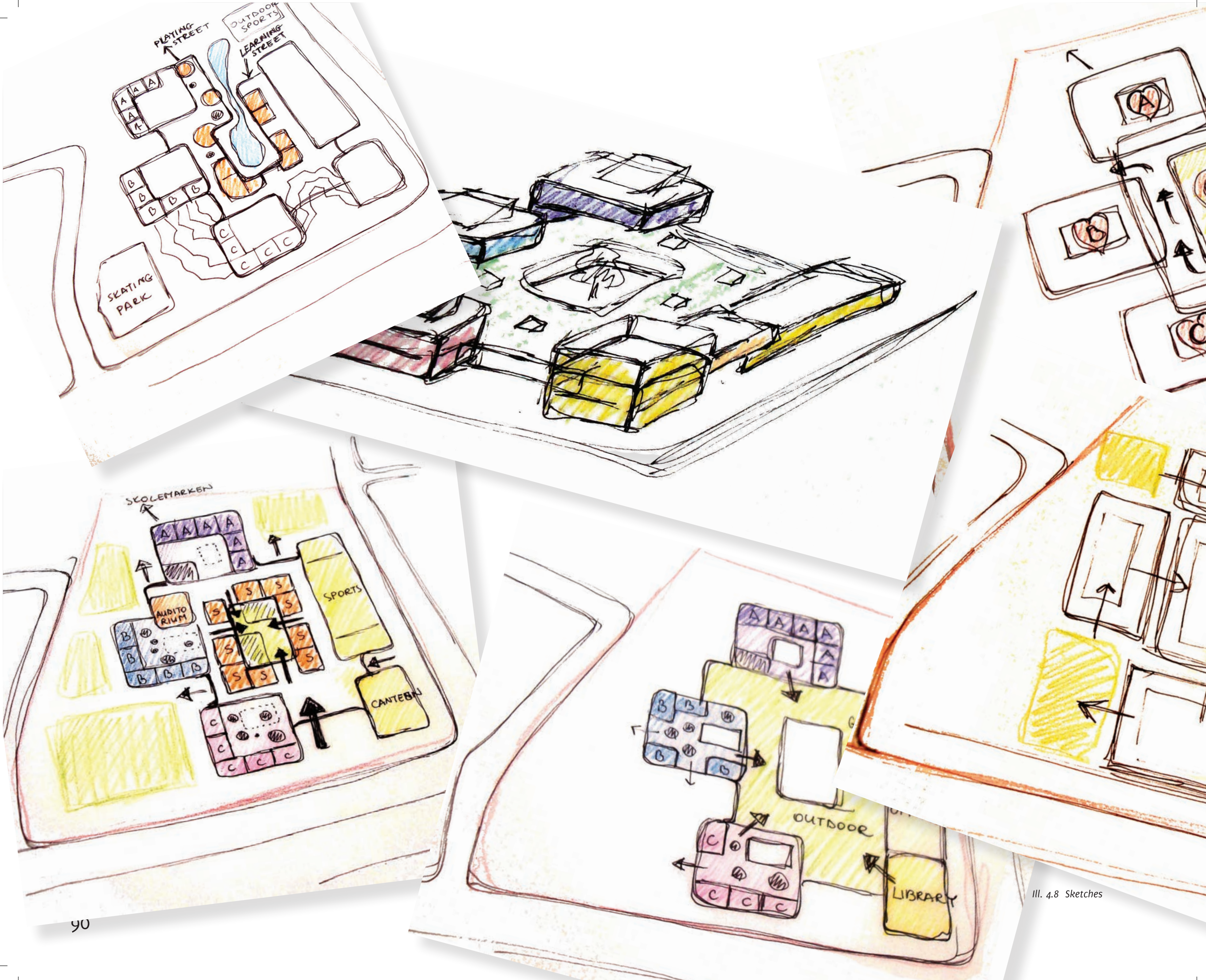
+ *Different function in each wing creates easy read-able form*
+ *Good integration between inside and outside*
+ *Good daylight conditions*
+ *Many semi-private spaces*

- *Dynamic form in strong contrast to surroundings*
- *No integration with existing structure*

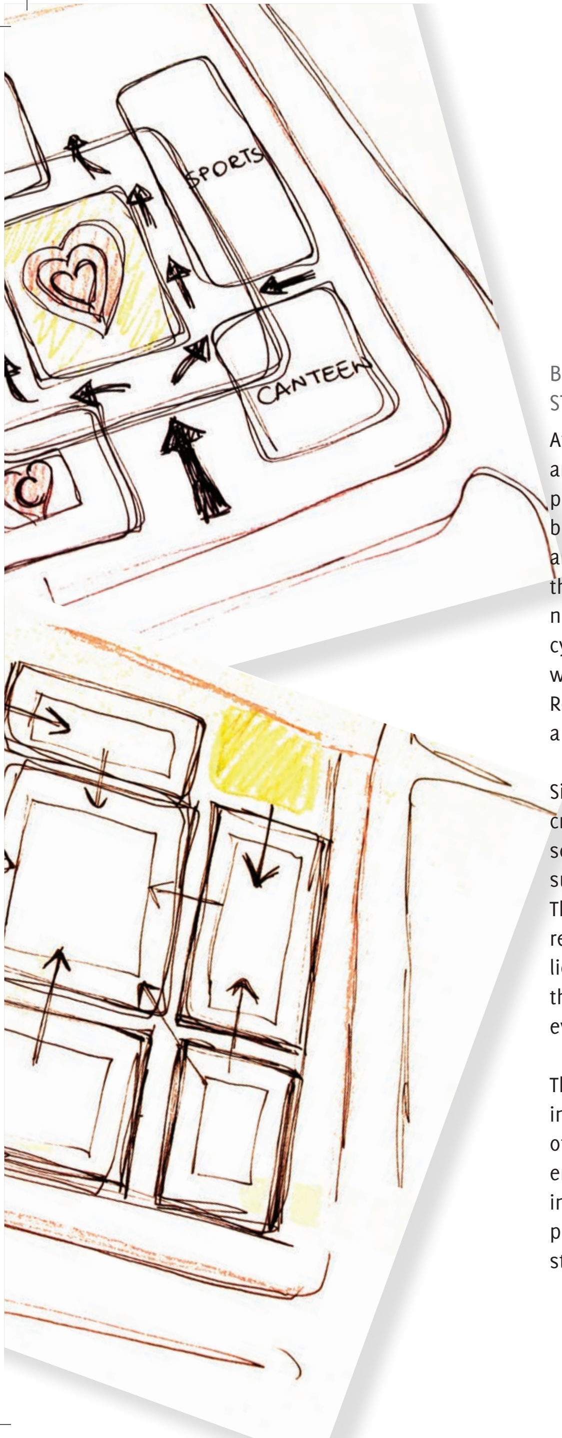
+ *Relates to urban structure and axes*
+ *Perforated form appears inviting*
+ *Form follows functions*
+ *Good daylight conditions*
+ *Easy access to outdoor areas*

- *Complex form*
- *Contrast to the high buildings towards east and west*

Ill. 4.7 Form finding options



Ill. 4.8 Sketches

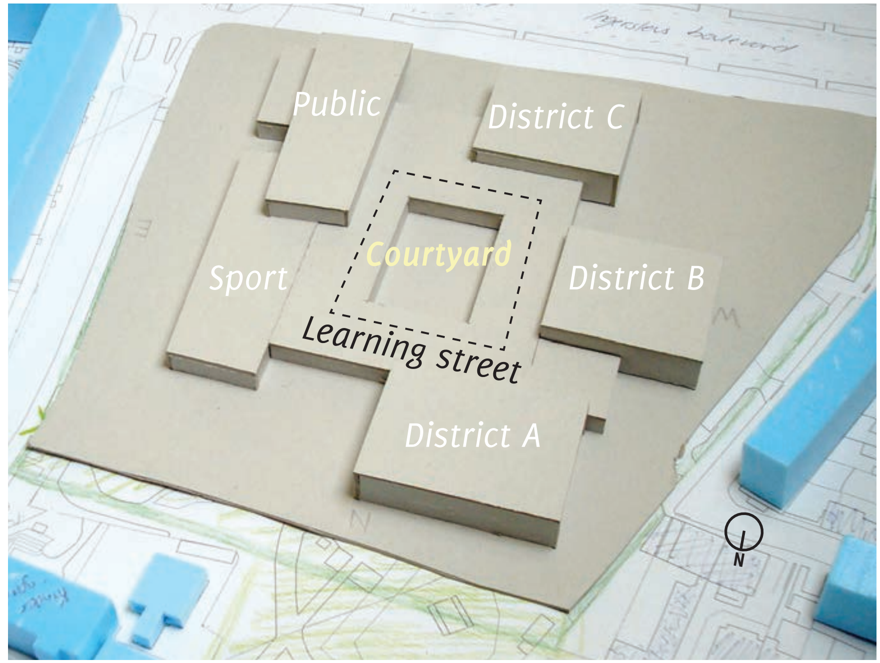


BLOCK STRUCTURE - THE CITY STRUCTURE IN A SMALL SCALE

After analysis of the surrounding areas in the very early stage of the project it was noticed that the city block is a common typology for the area. City blocks follow the edge of the site and have a semi-private inner courtyard. The feeling of privacy, intimacy and central orientation was seen as an appealing feature. Recreating similar atmosphere was a goal of the this proposal.

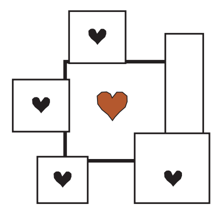
Since the aim of the project is not to create a residential building, but a school, a different expression than surrounding city block was needed. The school was divided into 6 easy recognizable units: 3 districts, public functions, sports facilities and the learning street, which unites everything into one whole.

The courtyard, formed by the learning street, serves as a main "heart" of the building. It is a green uncovered space dedicated to socializing, relaxing and studying. It is the place for the pupils of all ages and staff to enjoy and use.



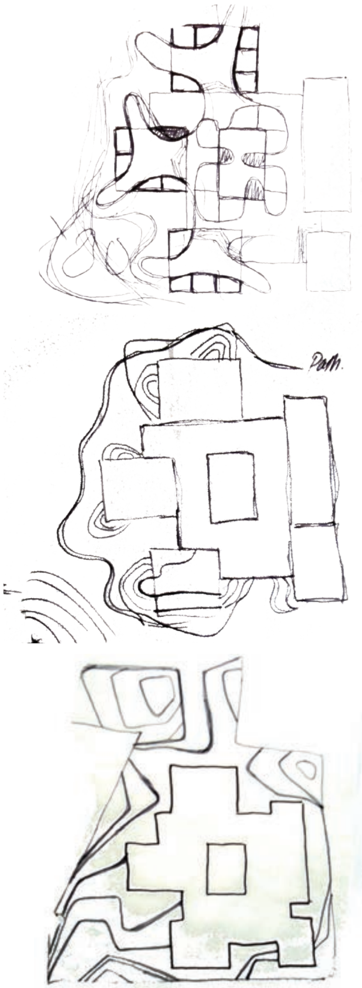
Ill. 4.9 Model of the proposal

Each cluster mimics the city block structure by organizing classrooms around central shared area. Each cluster or district thus becomes a smaller "heart" in each unit and enhances the feeling of togetherness and unity.



Ill. 4.10 Organization diagram

FORM AND LANDSCAPE
INTERACTION



Ill. . 4.11 *Different sketches for landscape intergration*

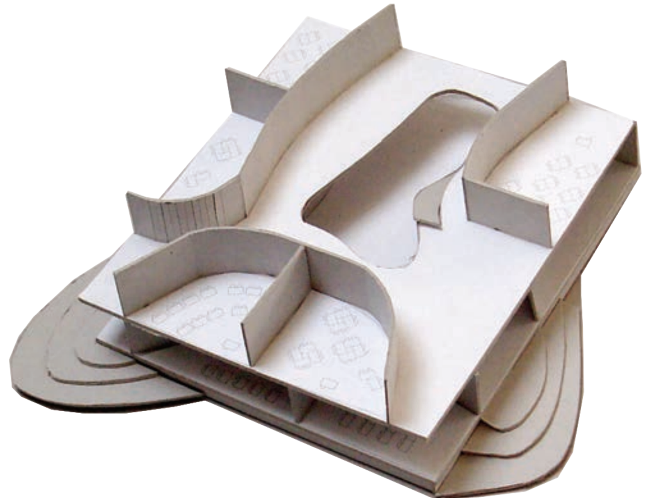
LINEAR BUILDING AND ORGANIC LANDSCAPE

To contrast the boxy shape of the building, dynamic and organic landscape was developed. It "enters" the building and becomes the part of the interior. Organic lines forming landscape in the outside are used in the interior to form inner walls and stairs.

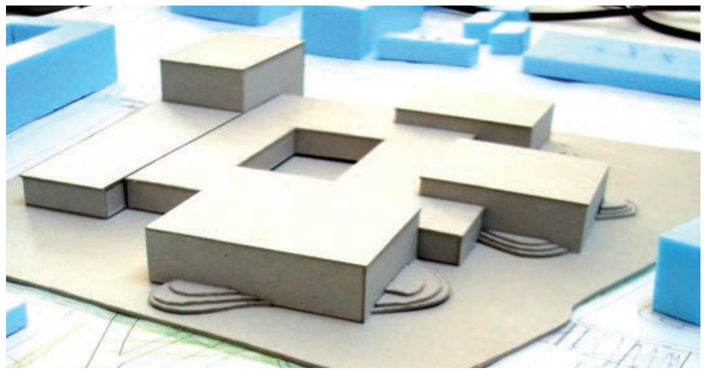
Unfortunately the result was too unpractical and appeared contrived. Curved walls also made placement of the furniture in the classrooms complicated.

Th boxy shaped building reminded too much of the traditional schools and could easily be mistaken for an office or any other public building.

Further steps to create a stronger identity of the school with its playfulness were necessary.



Ill. . 4.12 *Model of cluster B*



Ill. . 4.13 *Model of boxy volume and organic landscape*

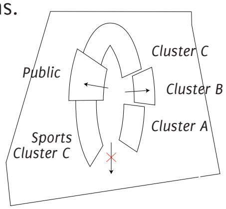
Ill.. 4.14 *CBS entrance*

Ill. . 4.15 *CBS interior*

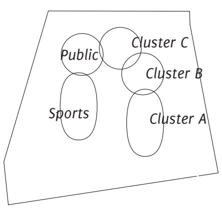
CURVED BUILDING FORM AND LINEAR LANDSCAPE

The next step in the design process was a reversed tactic - exploring the possibilities of the organically shaped building and more linear landscape. The process of design started with simple forms of ellipse s and circles. Two ways were chosen for the form finding:

1. Taking ellipse form and splitting it into smaller pieces, in this way forming rooms for different functions.



2. Assigning separate shapes for different functions.



The big semi-public inner courtyard was formed in both cases and became a focal point for the further process.

Ill. . 4.16 3D sketch of volume version I

Ill. . 4.17 3D sketch of volume version II

Ill. . 4.18 3D sketch of volume version III

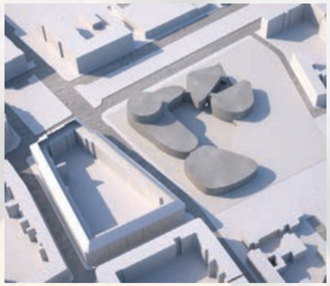
Ill.. 4.19 Model of the volume

FINAL FORM DEVELOPMENT

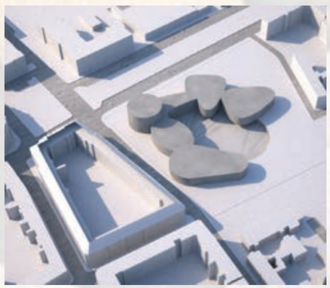
Since the previous investigation of ellipse or circle shaped building lead to quite controlled and more static volume of the new school, a more radical step was taken. Inspired by shapes of stones and cells the volumes of the school were twisted and turned in more playful ways. New dynamic architectural expression of the building helped to prevent from dullness and gave a desired and unmistakable identity for the new school.

It was decided to emphasize the yard in between volumes even more. A new garden or park should become a spot of attraction for pupils and school staff.

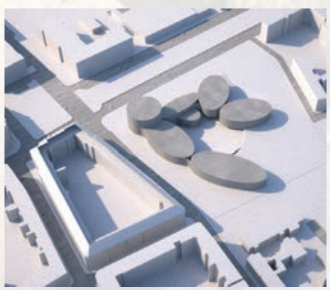
Public spaces should be placed around the edges of the site, visible and accesible from the street.



Ill. 4.20 Model of volume:



Ill. 4.21 Model of volume:

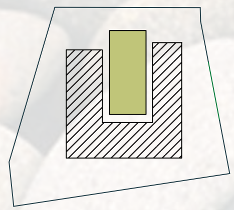


Ill. 4.22 Model of volume:

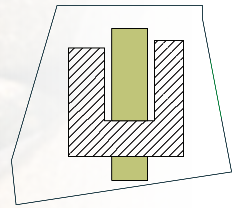
ENTRANCE TO THE GARDEN

It was decided that the garden should not be completely hidden and inaccessible to public, since the overall idea behind the project is an open and inviting school.

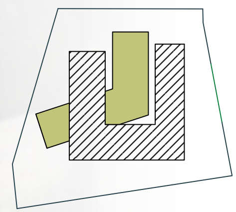
3 possibilities were explored:



1. The entrance placed only on the north side. The garden becomes isolated, has no connection with the skatepark and other activities on the south side of the site



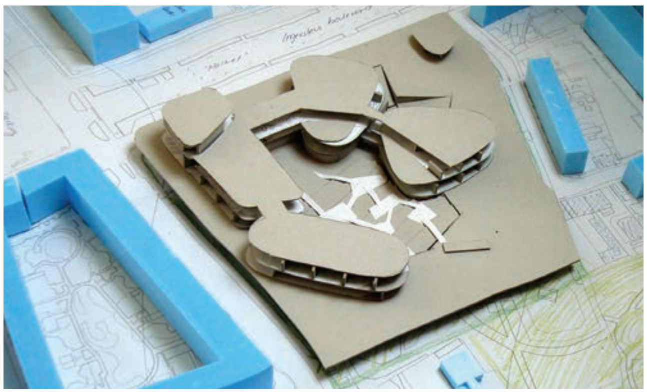
2. The entrance to the school must be moved to another location, because in this case the front of the building will gradually lower down to reach the sunken garden level. Too visible and inviting.



3. Entrance on the west side allows to use school entrance as it was originally proposed. Provides a good connection with the skate park. Hidden, but not completely.

Ill. 4.23 Diagrams illustrating different possibilities for the placement of entrance to the garden

Ill. 4.24 Model of the final volume: view from the main street



Ill. 4.25 Model of volume seen from above

Ill. 4.26 Model of volume: ground floor

Ill. 4.27 Model of volume: first floor

INDOOR CLIMATE – EARLY INVESTIGATIONS
DAYLIGHT

VE-SIMULATIONS

An early investigation on a simplified model of one of the districts is performed using a building performance analysis tool - Virtual Environment.

By using FlucsDL tool the daylight factor will be examined in relation to the glazing area in classrooms. In the shared areas skylights are used for improving quality of the indoor environment.

A simple model of two storeys with 7 identical classrooms and a shared area on each floor is modeled and rooms that are marked on illustration 4.28 are simulated.

Physical measurements:
Size of 30x22m on two floors

Groundfloor:
›7 classrooms of 60m2 (6x10m)
›shared area of 260m2 facing the North (10x26m)

1st floor:
›7 classrooms of 60 m2 (6x10m)
›shared area of 260m2 facing the South (10x26m)
Glazing area:
Classrooms – 35% of floor area – 8,7x2,4m window
Shared area – 13% of floor area – 10x3,5 window

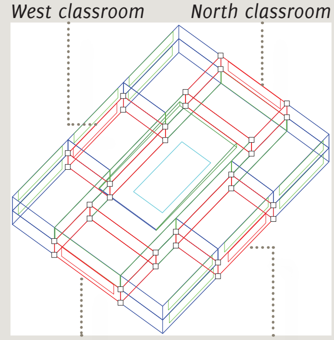
DAYLIGHT ANALYSIS

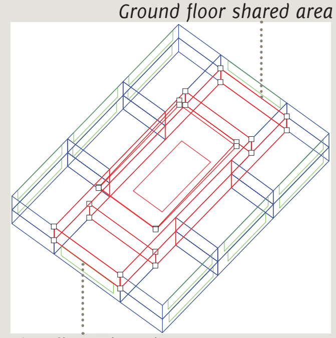
The results are shown on the page to the right. In terms of the glazing area, the glass percentage of 45% of the floor area proved the best daylight quality in classroom by giving 2% of daylight factor in the darkest corner. The percentage is too high though compared to the one recommended in Sbi 212 of 15% of the floor area. Therefore a risk of overheating and glare in the room must be considered.

Investigation of the shared area has shown a great contrast between the brightest and the darkest spot in the room by having 26% of daylight factor next to the window and barely of 1% - deep in the room.

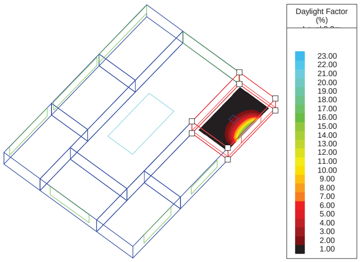
Therefore a simulation with skylight is performed which indicates that by using a skylight in the shared area an issue with dark spots can be solved and even completely eliminated.

Further investigation must be performed to investigate an affect of employing glass in the inner walls to let the light from one room to another as well as the influence of daylight on the ground floor shared area through the cut out in the floor.

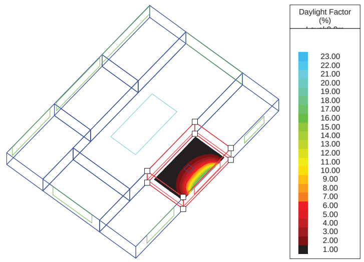




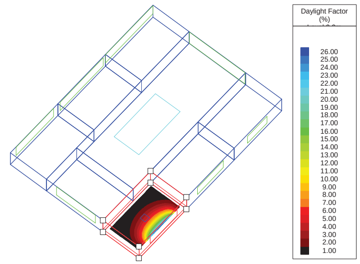
Ill. 4.28 Model in VE



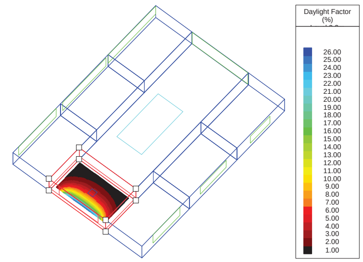
Ill. 4.29 15% of the floor area - window size 4,5x2m



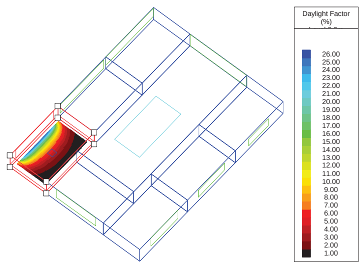
Ill. 4.30 20% of the floor area - window size 6x2m



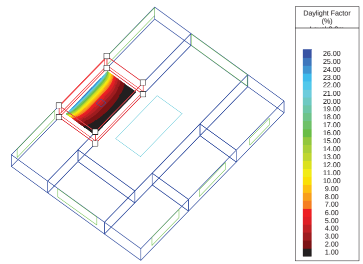
Ill. 4.31 25% of the floor area - window size 6,2x2,4m



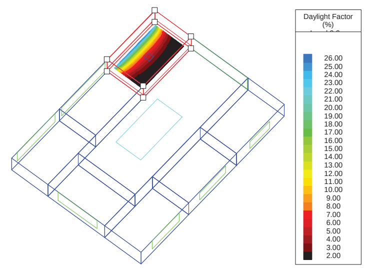
Ill. 4.32 30% of the floor area - window size 7,5x2,4m



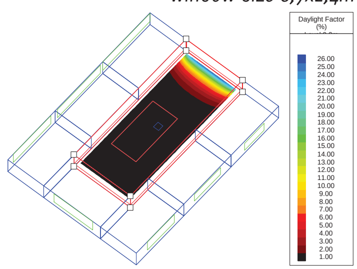
Ill. 4.33 35% of the floor area - window size 8,7x2,4m



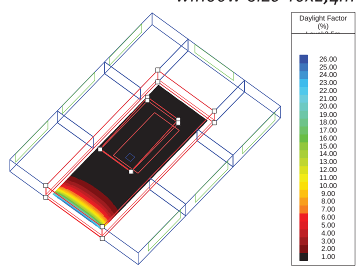
Ill. 4.34 40% of the floor area - window size 10x2,4m



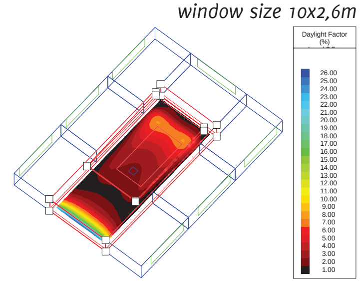
Ill. 4.35 45% of the floor area - window size 10x2,6m



Ill. 4.36 Ground floor shared area facing the North



Ill. 4.37 1st floor shared area facing the South



Ill. 4.38 1st floor shared area with a skylight

SHADING ANALYSIS

Above mentioned simulations show a high risk of overheating due to relatively high glazing percentage on the facades. Different shading devices will therefor be investigated in order to asses the benefit of adding solar shading and avoiding solar gains during the summer.

Shading devices such as overhangs, vertical and horizontal louvers as well as curtain net have been investigated without making any changes in thermal settings.

Number of overheating hours above 26 and 27 degrees during the occupancy time from 8:30 - 16:00 are shown on the charts 4.45, 4.46.

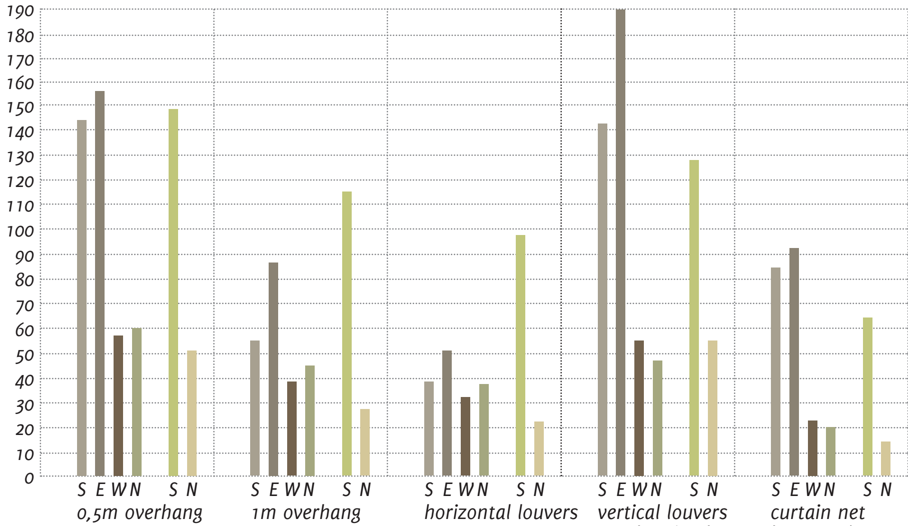
Ill. 4.40 0,5m overhang

Ill. 4.41 Horizontal louvers 100mm

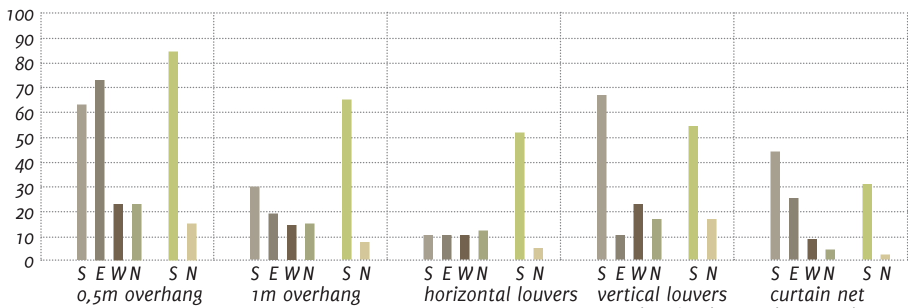
Ill. 4.42 1m overhang

Ill. 4.43 Vertical louvers 100mm

Ill. 4.44 Curtain net



Ill. 4.45 *Overheating hours above 26 degrees*



Ill. 4.46 *Overheating hours above 27 degrees*

The results show the efficiency of different shading devices according to different room orientation.

Overheating risk in the south classroom can be easily controlled by using 1 meter overhang. Horizontal louvers and net curtain prove efficient as well.

Horizontal louvers and curtain net are also very applicable to the east side room, whereas overheating in the west room can be controlled by any kind of shading.

However, one should consider how high temperature gets above 26 and 27 degrees. The temperature-graphs from May until September are shown in appendix 03.

The shading devices are set on continuosly which can affect daylight factor and obstruct views.

South classroom
East classroom
West classroom
North classroom
South shared area
North shared area

DAYLIGHT ANALYSIS

Influence of different shading devices on daylight factor must be evaluated in order to make a balanced choice without compromising neither thermal comfort nor daylight.

The results of daylight factor in percentage are shown on the plan to the right and compared in the table 4.48. It describes the minimum, average and maximum values which helps to evalute the intensity factor which is recomendable at the maximum of 5.

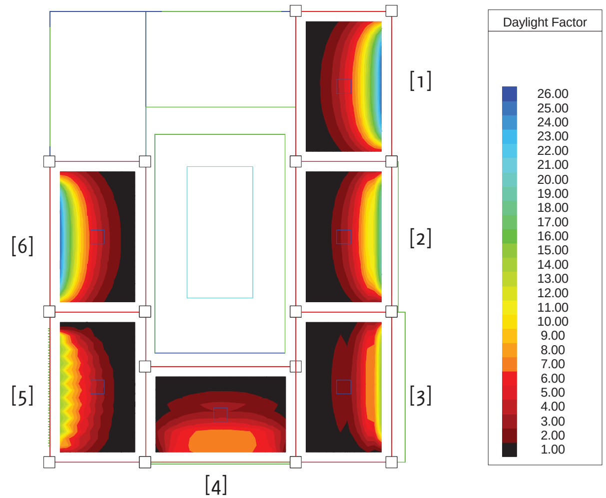
The daylight factor in all rooms does not get reduced significantly by any shading type and remains decent next to the inner wall. Most of the rooms, however, have a high contrast while horizontal louvers demonstrate better contrast result by having 0,7% at the least and 7,7% at the most lit spot.

Unfortunatelly FlucsDL cannot calculate a daylight factor with curtain net since it is applied to the glass in glazed constructions with a shading coefficient of 0,76. Other shading devices are designed as physical obstruction elements.

Though an issue of too low daylight factor next to the inner wall indicates that a further optimization is needed.

Shading devices:

1. Without shading
2. 0,5m overhang
3. 1m overhang
4. Horizontal 100mm louvers
5. Vertical 100mm louvers
6. Curtain net



Ill. 4.47 *Daylight factor with shading devices in plan*

Daylight factor %	[1]	[2]	[3]	[4]	[5]	[6]
Min.	0,7	0,5	0,5	0,7	0	-
Average	6,5	4,8	3,5	3,6	4,2	-
Max.	25,7	19,9	14,9	7,7	14,9	-

Ill. 4.48 *Daylight factor with shading devices*

SYNTHESIS

THE GARDENS
URBAN, LEARNING AND PLAY

The outdoor areas are an important part of the project in order to vitalize the area and make it relevant to all groups of children and school staff, as well as contribute to the district.

To distribute the activities for each group of children the master plan is divided into 3 zones: urban garden, learning garden and playing garden.

URBAN GARDEN

The urban garden consists of skatepark, bmx area, Le parkour training ground and similar playgrounds designed for promoting active lifestyle. The urban garden is clearly visible from the street and appears inviting. It is dedicated for B and C kids, as well as residents of the area. Concrete is the main material, because it is the most durable material for skating, rollerblading, etc.

LEARNING GARDEN

The learning garden is the area inbetween the volumes of the school. It is sunken 4 meters down from the street level so that it must be accessed by going down the ramp and inbetween the volumes of clusters B and C. The learning garden is difficult to see from the street for passers-by, but it is not completely hidden. A hint that something interesting is going on can be seen. This appears intriguing while at the same time sending a message that this area is more private.

The place is divided with platforms and is stepping down, creating places for sitting, gardening, water elements, etc. Smaller gardens for growing vegetables and herbs, which later can be used for food in the canteen, are placed within the learning garden.

A very important feature is the easy connection between the garden and the subject rooms. Every classroom on the -1 level has a direct access to the outside. While having lessons of biology or chemistry, pupils are able to go out and do real-life experiments using water, soil or plants from the garden, so the garden becomes a place not only for relaxing, but contributes to the school's curriculum.

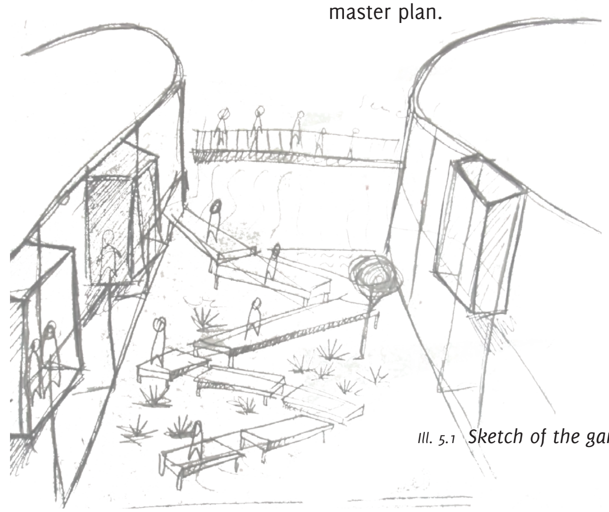
PLAYING GARDEN

The last zone is on the very north side of the site. This playing garden is dedicated to the youngest kids, both school members and residents of the area, and points toward Skolemarken. Various playgrounds and water activities are placed there.

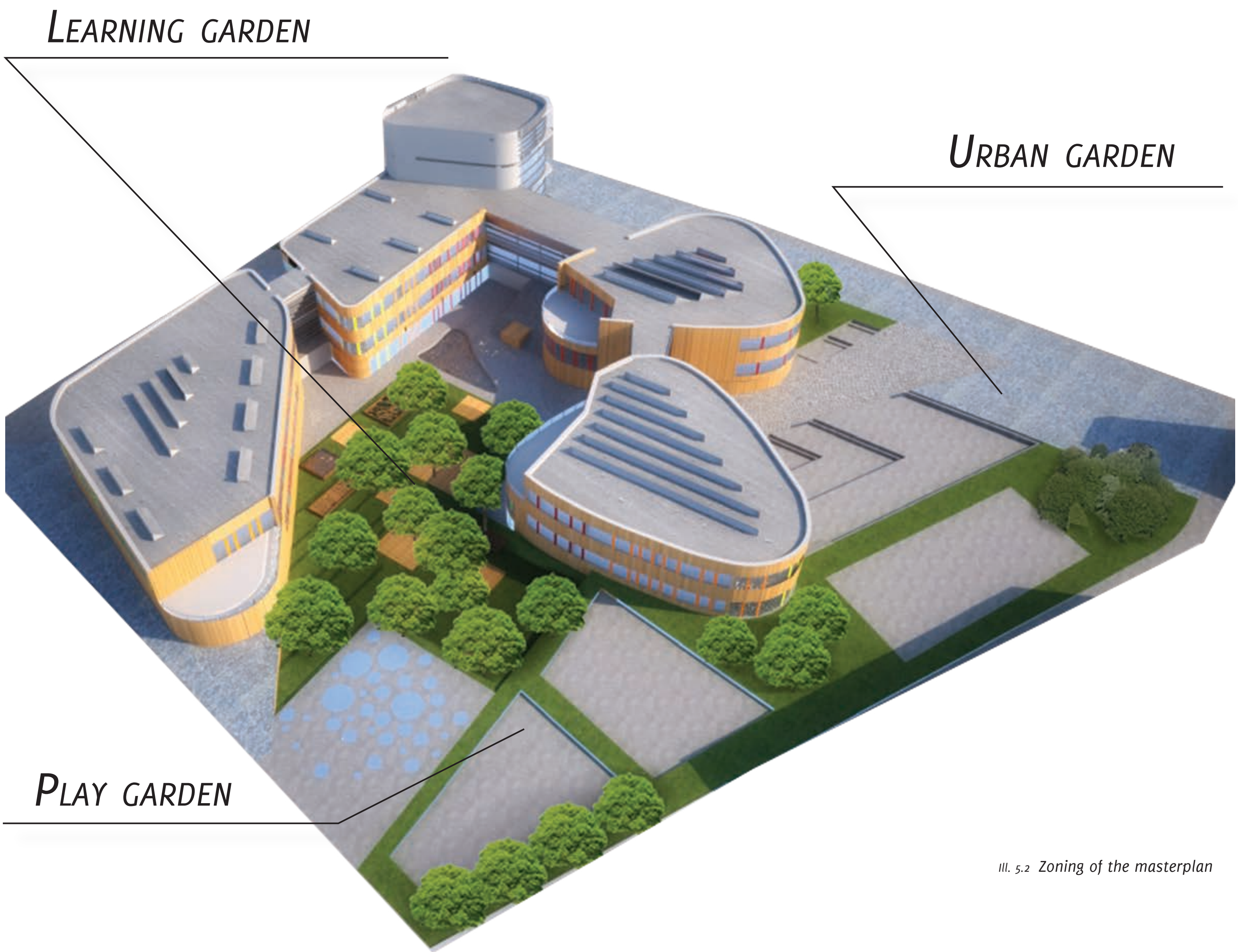
Even though in the plan the landscape might look strict, a rich use of greenery and materials such as wood for the platforms in the learning garden, colorful concrete in the urban garden and water fountains in the playing garden gives a soft and children-friendly feeling for the area.

STRUCTURE

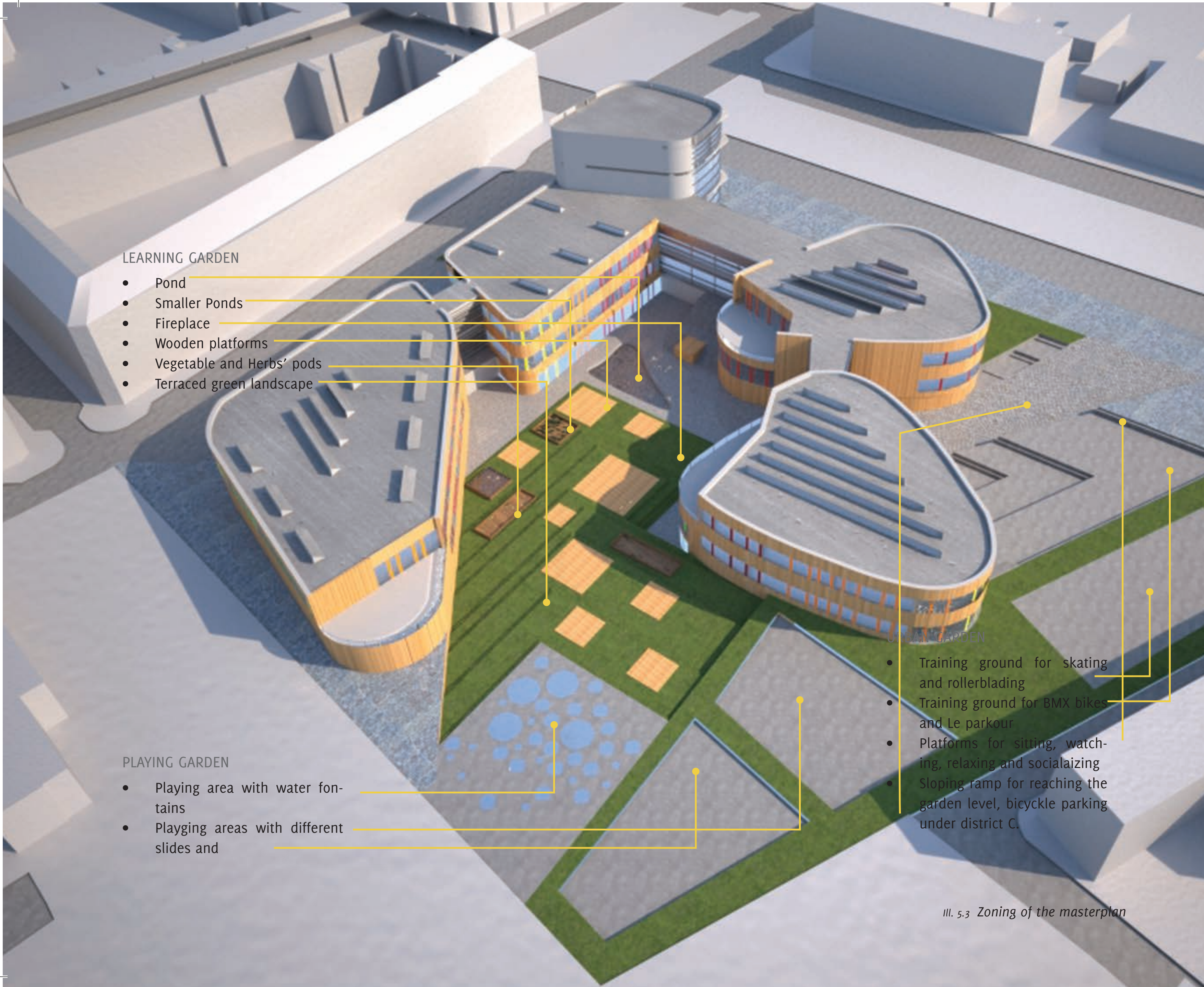
The feature connecting all the areas together is the linear expression of the landscape. A grid, based on the direction of streets, helps to organize and structures the overall master plan.



Ill. 5.1 *Sketch of the garden*



Ill. 5.2 Zoning of the masterplan



Ill. 5.3 *Zoning of the masterplan*

Ill. 5.4 Le Parkour training ground

Ill. 5.5 BMX track

Ill. 5.6 Skatepark

Ill. 5.7 Platforms

Ill.5.8 Terraced landscape

Ill. 5.9 Pots for flowers and vegetables

Ill. 5.10 Water

Ill. 5.11 Water playground

Ill.5.12 Water playground

Ill.5.13 Slides

Ill.5.14 Climbing wall

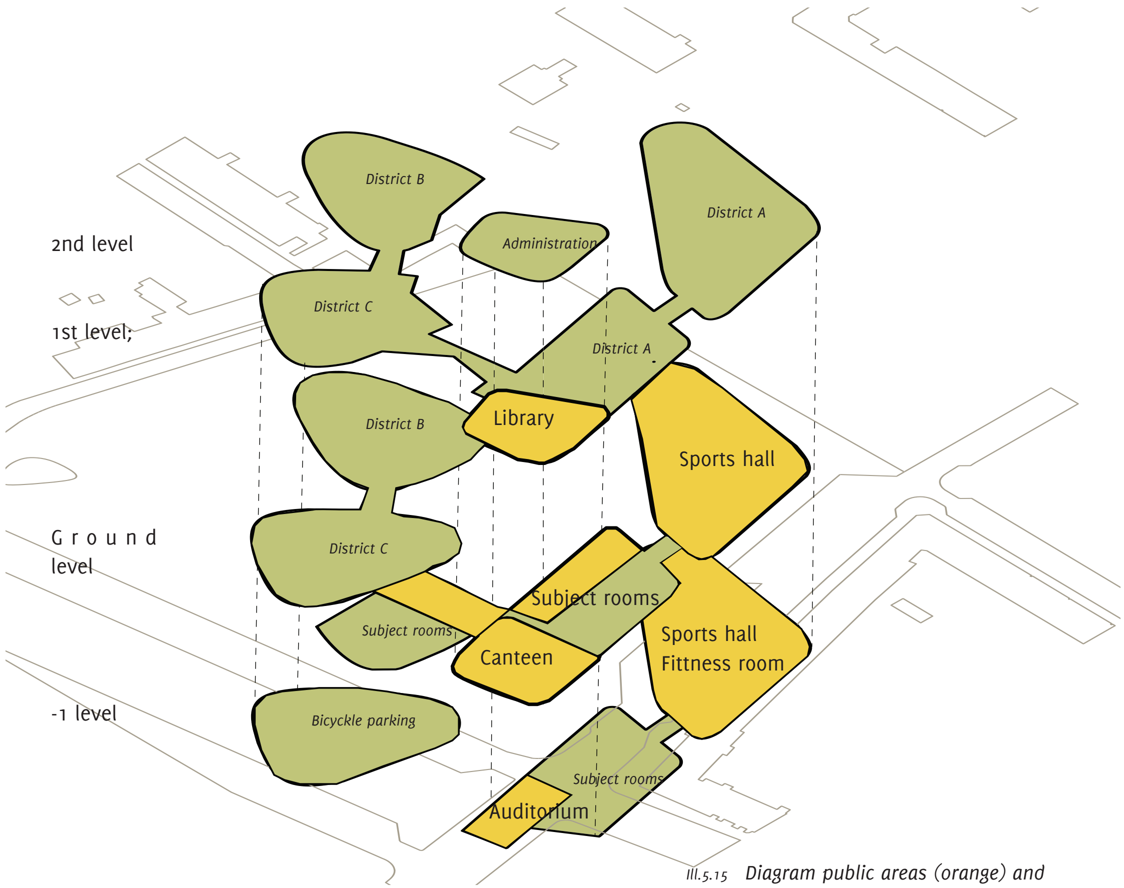
THE CITY AND THE SCHOOL
MIXED FUNCTIONS

SCHOOL AND CITY RELATION

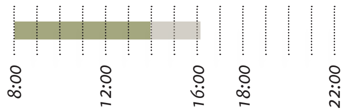
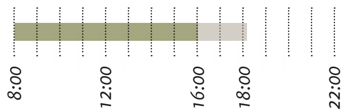
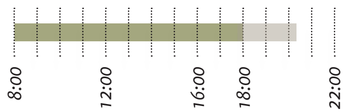
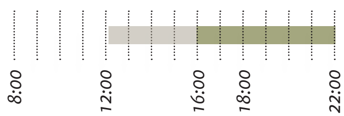
According to the vision from the municipality of Aarhus the residents of the area and guests should benefit from the new project. This is done by creating a school, where some of the functions could be used not only by the school members, but by the guests as well. The school is designed in a way so it is easily readable where the public functions are – the transparent clear volumes of the canteen and the library are inviting and open to the residents.

The subject rooms placed on the ground floor, such as music and art rooms and theater area, can be used by residents as well. Moreover, the auditorium on the -1 level could be rented and used for district meetings, lectures, etc.

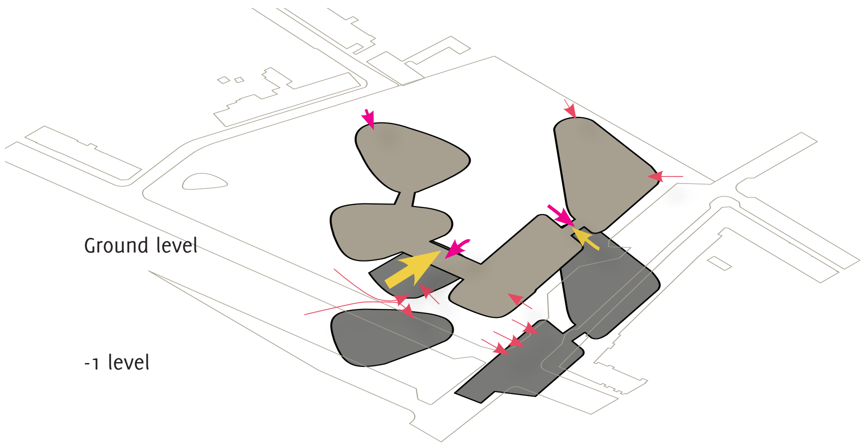
The sports hall and fitness room also contribute to the area when not used by school members.



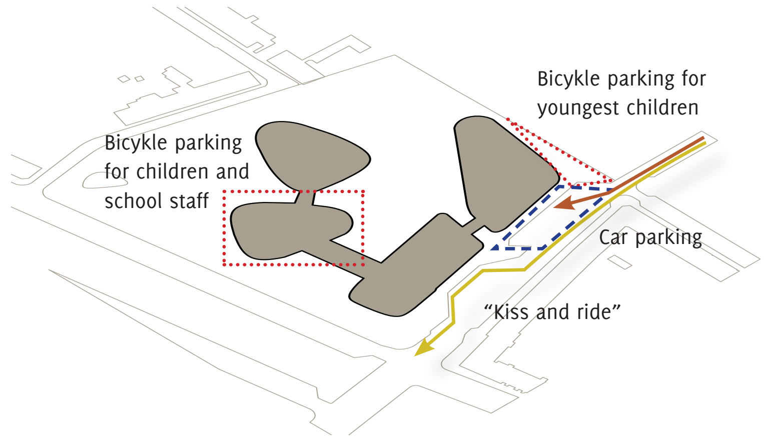
Ill.5.15 *Diagram public areas (orange) and private areas(green)*

	Timetable	Zones of activity	Notes
Pupil (A)		District A, library, canteen, shared areas inside the district, sports hall, playing garden	From 8 am to 2 pm the youngest pupils have classes, 2pm - 4pm - SFO
Pupil (B,C)		Districts B and C, shared areas inside both districts, library, canteen, sports hall, subject rooms, workshops, urban garden, learning garden.	Older pupils have classes from 8 pm to 4 am, and sometimes stay a few hours longer for sports or homework.
Teacher		Administration offices, districts, teachers' room in the districts, canteen, library, fitness room, learning garden.	Teachers' working hours starts from 8 am and ends at 6 pm, later they can use fitness room and sports hall or stay in teachers' lounge preparing for lessons.
Guest		Canteen, library, sports hall, fitness room, subject rooms (arts, music, theater)	Guests could start using school and library in the afternoon, especially starting from 4pm when there are fewer children in the school.

FLOW AND TRAFFIC



Ill. 5.16 *Entrances to the building*



Ill. 5.17 *Diagram of flow and traffic*

ENTRANCES

The main entrance is placed in the south side, it is used both for school members and public.

Main entrance (for public, school staff and pupils)

Entrance use by school staff and pupils only

Entrance used by both school staff, pupils and public

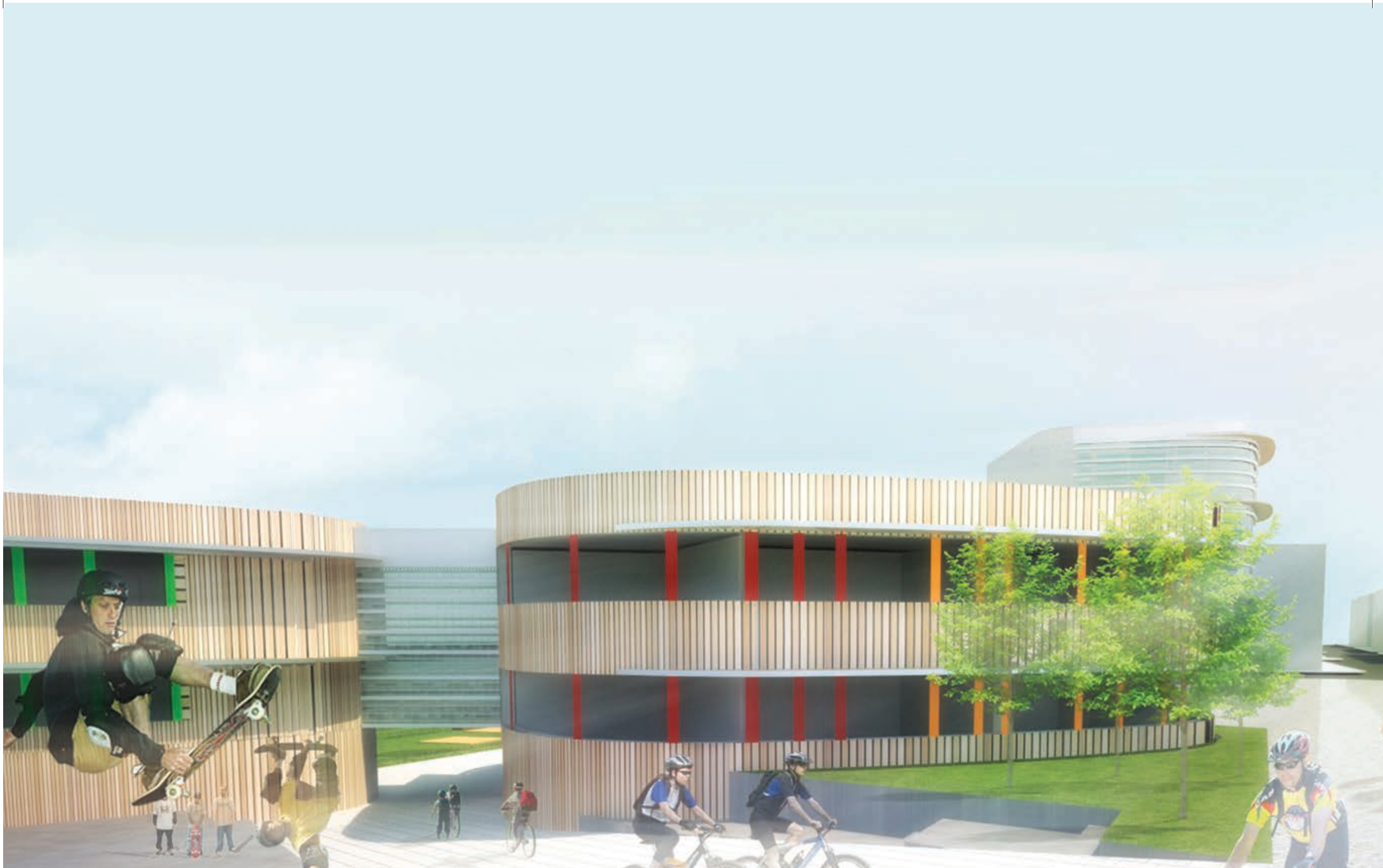
Secondary entrances for school staff and pupils

ARRIVAL

Beneath district C bicycle parking is located. The parking is roofed and 900 sqm in size. This parking is dedicated the kids from districts B and C and the oldest children from district A. The youngest pupils have a small open parking lot close to district A.

"Kiss and ride" area is placed on the east side of the site. This area is also used as bus take-off and drop-off area, when children are going on excursions.

14 parking spaces and 1 parking space for disabled persons are located on the far east side. The aim is to encourage users of the school to use bicycle, public transport or to walk by foot.



Ill. 5.18 The ramp to the bicycle parking and the garden

ARCHITECTURE AND LEARNING ENVIRONMENTS

STRUCTURE

From the chapter "School Architecture - Focus areas" (p. 61) various important features are derived in order to integrate them into the school organization.

The illustration at the right shows the general thoughts on how these functions will interact and create spatial diversity in various important learning environments at school.

HOME BASE

Home classrooms replace traditional classrooms, and can be described as the place the students have a real affinity for, and which also is associated with a permanent group of teachers.

They create a fixed point in the course of everyday life.

INTRODUCTION ROOM

Introduction rooms facilitate project work. The rooms' immediate task is to animate discussion and to provide the frames for smaller presentations of projects.

WORK STATION

Smaller work stations stem from the desire for differentiated teaching.

HOT SPOTS

Social meeting spot

SHARED AREA

A room that encourages the meeting with others. Community provides security and opportunity to interact with each other across class and age.

STOREROOM

Because of the versatility of the classrooms, it is necessary to create space for storage of materials, props and the pupils semi-finished products.

RECREATIONAL SPACE

Not all rooms must be assigned a function. The pupils must also have the opportunity to put their stamp on the school.

SUBJECT ROOMS

The traditional subject rooms have often been divided into well-defined subjects. Now a more interdisciplinary education with an open environment is sought.

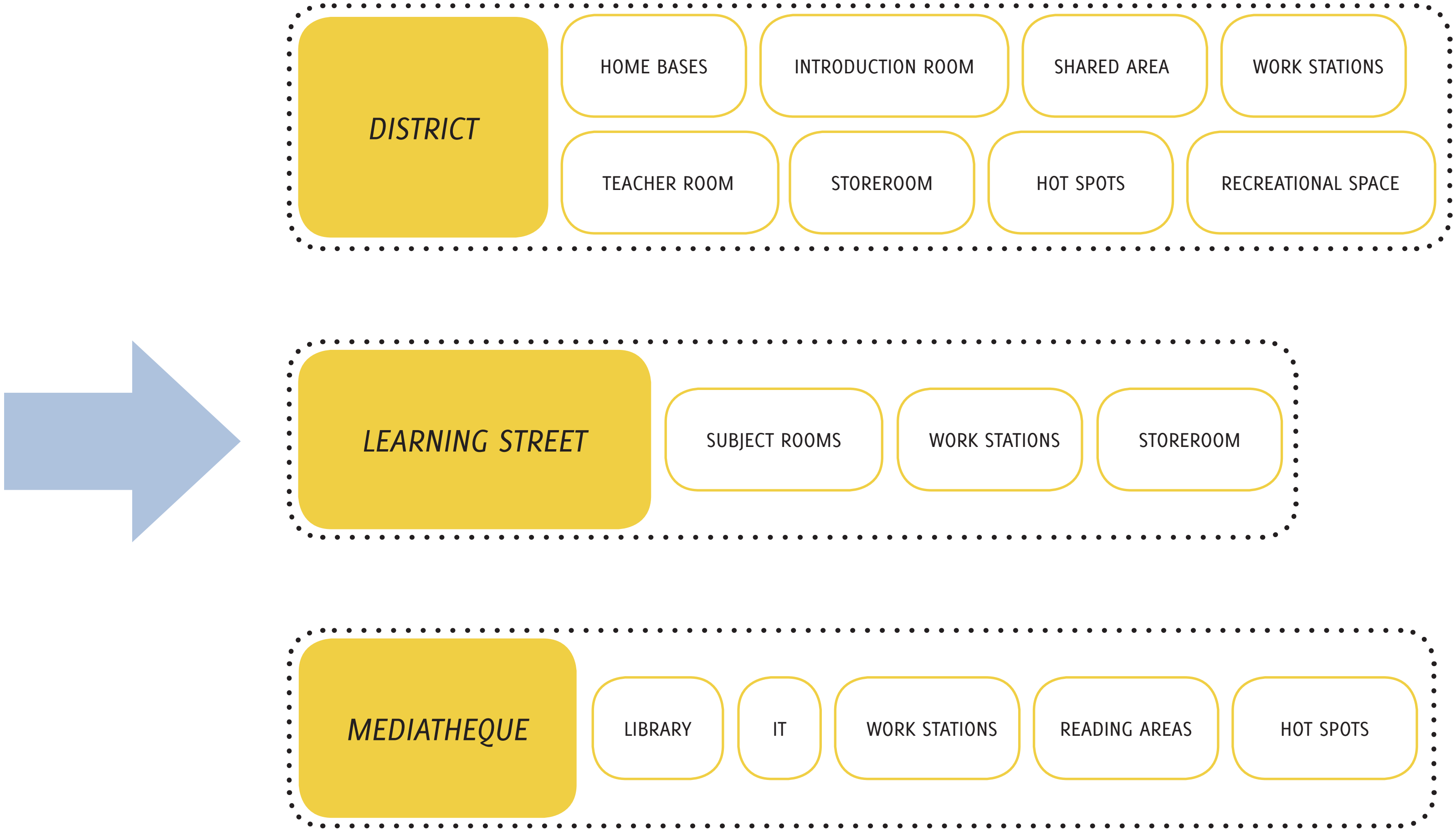
MEDIATHEQUE

Replaces the traditional school library and offers not only the loan of books but also the use of multimedia such as computers, video editing and the like. Furthermore, the Mediatheque must accommodate meetings, breaks and be room to hold meetings, breaks and study areas.

TEACHER ROOM

The teacher-pupil relationship has changed. The teachers are no longer hidden behind a pulpit. Instead they move around in class to help and discuss with the pupils. Therefore, they need a place to stay when the pupils are immersed in their work - a place that facilitates oversight and contact, and which functions as a contact point where the pupils at all times can turn.

Ill. 5.19 Diagram of different functions that the new school should contain to ensure differentiated learning



Ill. 5.20 General diagram of main learning environments at the school.

ABC

PEDAGOGICAL PROFILE OF THE SCHOOL

This project seeks to create an overall organization that is consistent with the different stages of development, as earlier mentioned.

The new school can be divided into three main divisions:

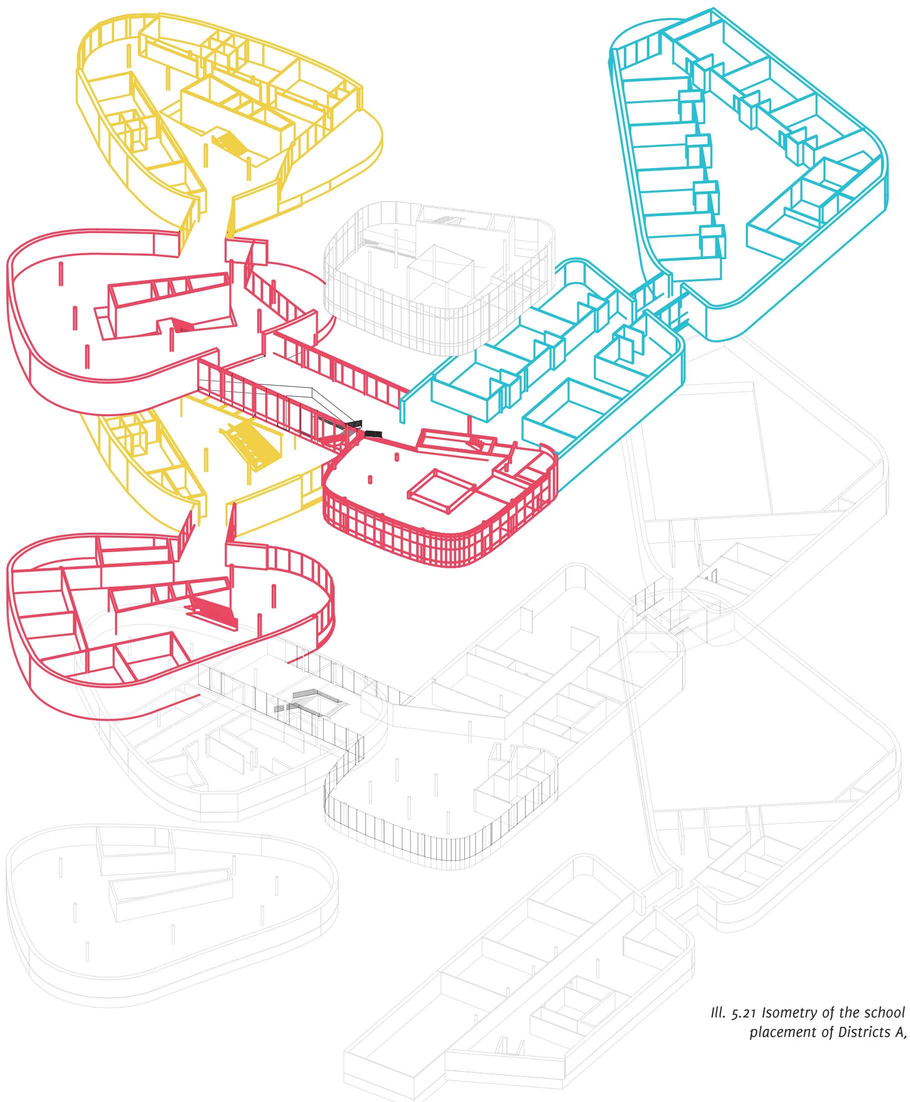
- A (Primary School: 0-3rd grade incl. SFO)
- B (Middle School: 4-6th grade)
- C (Final School: 7-9th grade)

To further accommodate each child's individual needs and learning styles, various spatial organizations are explored. By combining knowledge about age differentiated space and learning flexibility different room structures are developed, based on the different needs that characterizes A, B and C.

ORGANIZATION

The illustration at the right shows an overview of the school's final organization. The structure of the school varies between the more open communal areas and the more private and closed classrooms and offices. While the public functions, such as canteen/cafe and sports center are oriented toward the urban space at street level, the open communal areas are more inward oriented toward a green sunken courtyard.

The different needs in relation to age are reflected in the organization of e.g. classrooms and common areas in the sections A, B and C as well as in the orientation of each section toward other school functions. For example the pupils in primary school (A) requires the common premises in close association with the classrooms, while children in final school (C) need to be able to operate at a greater distance from the classroom.



Ill. 5.21 Isometry of the school showing placement of Districts A, B and C

A: Pupils in primary school need safe and well-defined surroundings. The classroom is particularly important for younger students because it helps increase the sense of overview and homeliness while at school. As group A also requires more supervision a larger classroom with multiple workspaces integrated into the room is developed. A closer contact with the teachers is created by bringing together the various activities at the same time increasing the children's sense of security.

B: In the middle school pupils begin to focus more on community and they identify themselves in relation to the group. Meeting places are very important here but also the ability to retreat into smaller niches must be provided for.

C: In final school focus is on the individual. Pupils would like to define their identity through diversity and openness, and have far more need to be able to operate at a greater distance from the classroom. Therefore a close connection with the larger common areas, such as the cafeteria and library, in the main building is created.

WORK STATIONS

The public school focuses on children's diversity and that requires an education form that takes into account that the educational goals can be achieved in several ways and at different speeds. Therefore, the traditional classroom is no longer sufficient, since teaching differentiation often creates a need to divide the class into smaller groups.

Pupils have different needs and it is necessary that learning environments and the different learning situations are clearly defined according to the need they meet. Here it has been important to create different degrees of intimacy in the layout of the various compartments.

A work station for group work is an essential aspect to facilitate differentiated teaching. For example, children with special needs require that the rooms can be divided into smaller units - where they can retreat without being disturbed by the outside world.

The challenge for the architecture is to create spaces that at once allow an openness that provides an overview and visual contact between the rooms and, at the same time are so confined that they protect against interference. In addition, it is essential that pupils quickly can get in contact with the teacher, and it should be possible for the teacher to have an overview of the pupil's work and whereabouts. The physical environment must offer nice places where you can work undisturbed and concentrated, with the opportunity to showcase pupils' various works, so they can benefit from each others experiences.

The school is designed with many different kinds of work stations; for individual work, for group work and workplaces where one or more classes can be assembled. The illustration to the right shows the different degrees of intimacy and noise.

CHALLENGES

The shared areas function both as workstations (group work) and as infrastructural nodes, and that put forth some requirements for the joint use of the areas. To meet this issue the flow areas have been separated from the work areas by creating "links" from the class areas to the work areas and from the district to the main building. By designing according to these links the dual function of the room is addressed limiting disturbance to the lowest possible extend without physically having to divide the space into smaller spaces.

STRATEGIES

PEDAGOGICAL PRINCIPLES
Learning Flexibility
Well-being
Age differentiation

↓

PHYSICAL ENVIRONMENT / SPATIAL STRUCTUR

Need for versatile rooms of different sizes

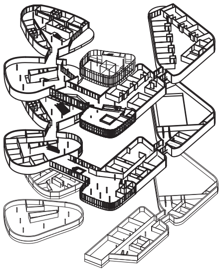
Need for different degrees of intimacy in the layout of the various rooms

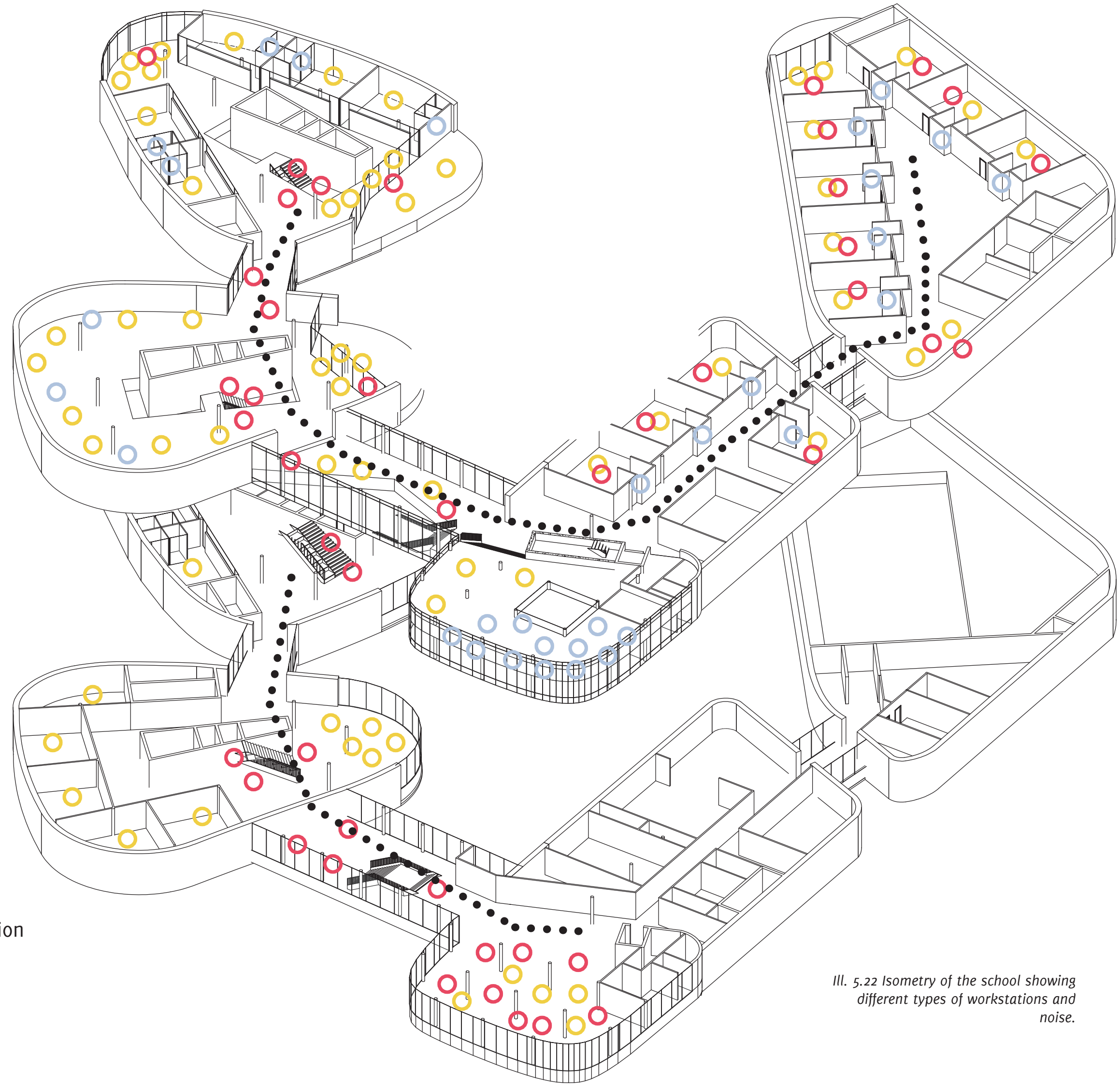
Need for well-defined rooms that protect against interference

Need for niches for group work

Need for extensive interaction between teacher and pupil as well as among the pupils

Need for outdoor areas that may be included as part of the learning environments





Ill. 5.22 Isometry of the school showing different types of workstations and noise.

DISTRICT - HOME BASE AND SHARED AREAS

COMMON SPACE

The common area is adjacent to the classrooms and contributes to both small workstations as part of teaching and to recreational space in the breaks. The teaching related furnishing in the common room creates small rooms in the large room that can be used both for individual work and group work. Storage rooms are located in the common room.

CLASS ROOM

The classrooms are arranged according to the classical ideals with four walls and a traditional classroom as well as an introduction space. However, it has more flexible teaching furniture than a traditional classroom. Despite the traditional design of the classrooms extra space can easily be created due to the close contact to the common area. A small niche is integrated into the classroom to provide for a quiet workstation to the pupils with special needs. Here they have a quiet space to concentrate and a better contact with the teacher.

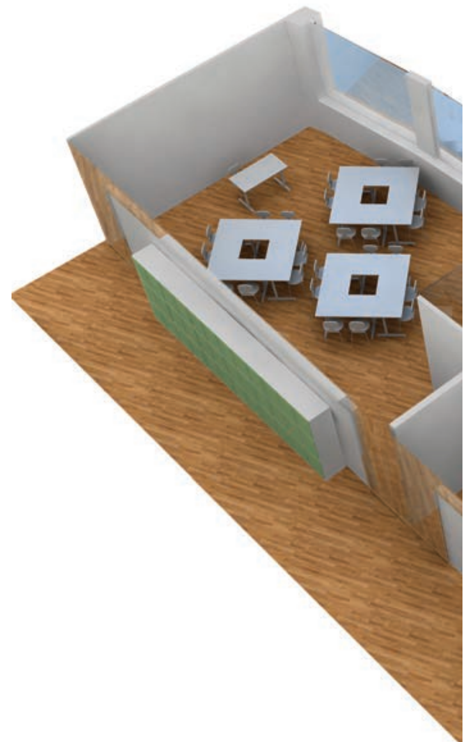
SPACIOUS TRANSITIONS

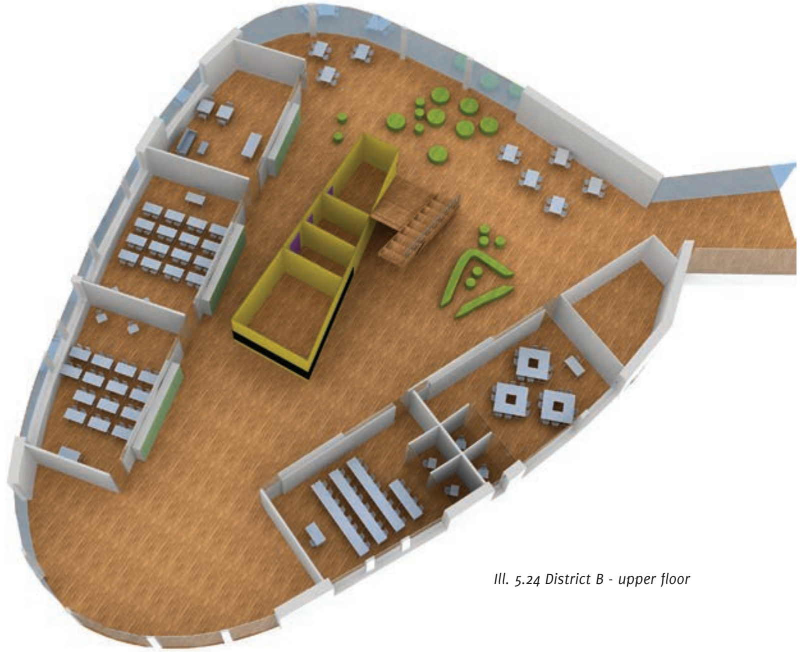
To create visual and spacious transitions from classrooms to common areas "locker walls" for the pupils are installed between each class door. These colored volumes emerges from a transparent glass wall and are among other things, helping to indicate the location of the classrooms. The repetition and rhythm of the "locker walls" helps to bind the large room together.

The glass panels around the boxes is contributing to create transparency and provide an overview and visual contact between the classrooms and common areas. The highly placed windows help to pull light into the back of the classroom while the lower placed windows and glass door provides for visual connecting. A whole glass wall has deliberately been ruled out in order to avoid too much visual interference between rooms as well as acoustic problems due to the hard surface. The glass panels also allow for swift contact between pupils and teachers, just as it is possible for the teacher to have an overview of the pupils' work and whereabouts.

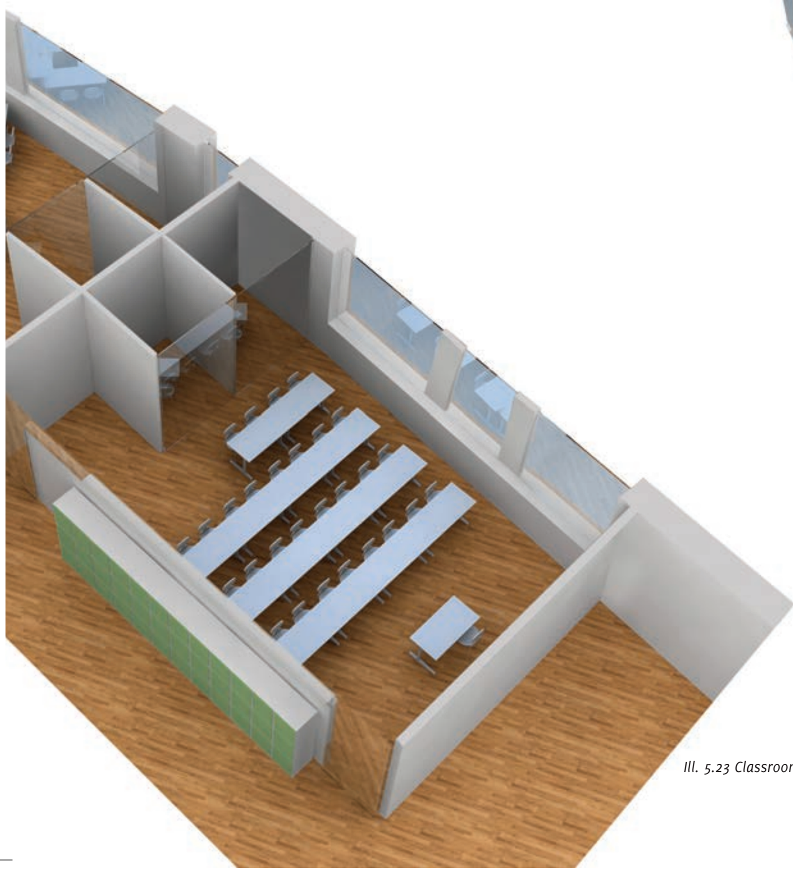
THE STAIRS

The stairs are centrally located and divided into two functional zones, transit and stay. The large seating steps indicate a social space where people meet and talk. Main Hall / stairs creates a double high room with light intake located below the ceiling. Light from the upper floor is pulled down in the sub-floor through the opening by the stairs.

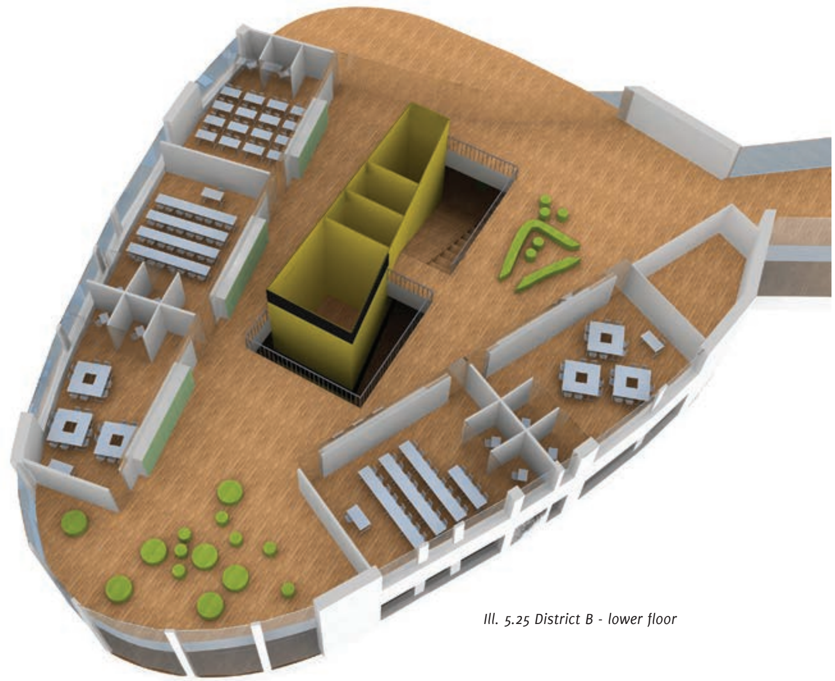




Ill. 5.24 District B - upper floor



Ill. 5.23 Classrooms



Ill. 5.25 District B - lower floor

EDUCATIONAL OPPORTUNITIES

The variation of room size and features within a district allows for differentiation in teaching. The more undefined common area requires a higher degree of self-regulation by the pupils and a higher degree of adult control in learning situations, compared with class rooms. In turn the multifunctionality of the common area ensures that there are no "dead" square meters when a class is on tour, in a subject room, in the learning street or across at the sports center. This organization allow for classes to borrow from each other's square meters more so than if the common areas were more isolated.

Ill. 5.26 District B - common area

INDOOR CLIMATE
DISTRICT - OPTIMIZATION

INTRODUCTION

Using the earlier described tool Virtual Environment, the final shape of the district B will be investigated.

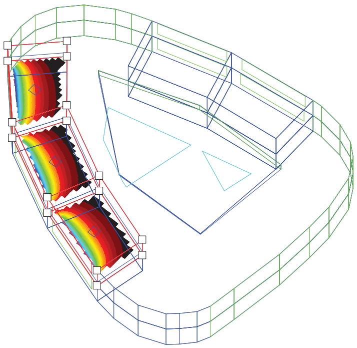
In order to optimize and confirm the quality of indoor climate, classrooms and shared areas will be checked for daylight quality, air humidity, temperature and pollution.

This will give an insight on how the building could be optimized in respect to indoor climate, daylight and energy through an adjustment of construction, heating and cooling strategies as well as the control of these.

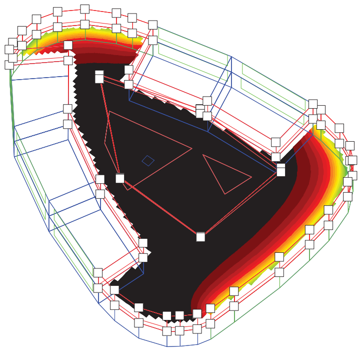
The aim is to modify the building until it reaches the requirements for category A for indoor climate.

As earlier mentioned following demands for Category A must be fulfilled:
› Permissible vertical air temperature difference – ‹2 C° [CR1752, A.2]
› Operative temperature in summer – 23,5-25,5 C°;
› Operative temperature in winter – 21,0-23,0 C°;
› If a cooling strategy is needed, 14 C° air must be supplied in 5 l/s/m2 during summer conditions;
› Design relative humidity for dehumidification – 50%;
› Design relative humidity for humidification – 30% [DSEN_15251, B.6]
› Heating setpoint – 21,0 C°
› Cooling setpoint – 25,0 C°
› CO_2 level – 810ppm

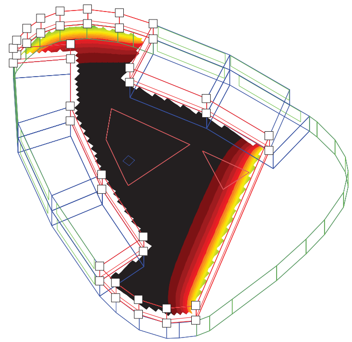
DAYLIGHT



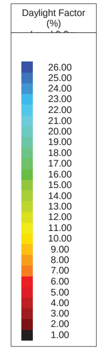
Ill. 5.27 *Daylight - classrooms*



Ill. 5.28 *Daylight - 1st floor shared area*



Ill. 5.29 *Daylight - Modified 1st floor shared area*



CLASSROOMS

Daylight factor analysis is performed to evaluate daylight quality in work areas, classrooms and shared spaces.

Classrooms are given windows of 8,7x2,4 m which constitutes 35% of the floor area. The results show quite high daylight factor in most of the room although a darker spot next to the inner wall is found which holds a dayligth factor of 1%. Another issue noticed is a great contrast between the brightest and the darkest spot in the room which indicates a risk of glare, thus a solution of solar shading might be considered.

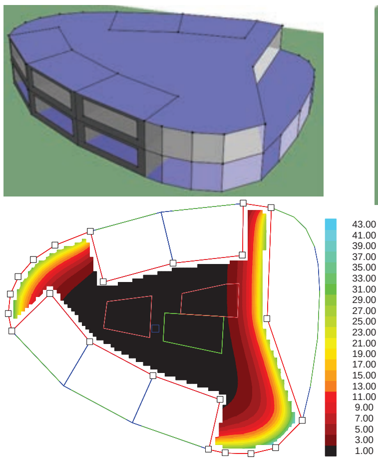
SHARED AREAS

Simulation on the shared areas shows that despite a huge glazing area in the facades towards the East and West, daylight factor is very low in the middle of the rooms yet reaching very high values just next to the windows (See ill. 5.28).

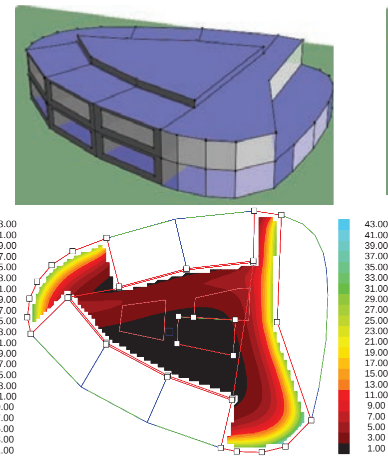
In order to bring more light into the shared spaces, the volume is being modified by cutting off a part of the 1st floor (See ill. 5.29). Doing this wil not only reduce dark spots on the 1st level, but will also bring in more light to the ground level shared area through the holes in the floor.

The daylight factor, however, is still unacceptable for the working areas in the middle of the rooms. This issue might be solved by means of skylights, benefit of which has been proved in early investigation. Therefore different types of skylights are applied to the model and results according to daylight factor are registered following.

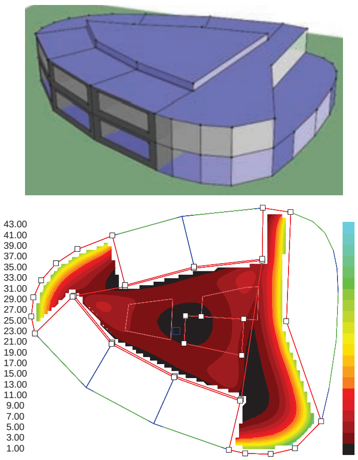
Due to high glazing percentage in the shared spaces, one has to be aware of overheating risk which can be increased by skylights. Therefor temperature is also being checked.



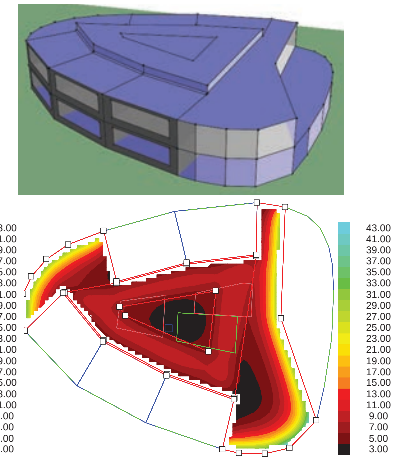
Ill. 5.30 *Daylight - no skylight*



Ill. 5.31 *Daylight - glazing towards north*



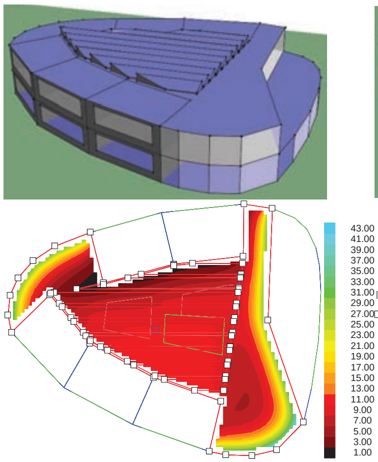
Ill. 5.32 *Daylight - glazing in perimeter*



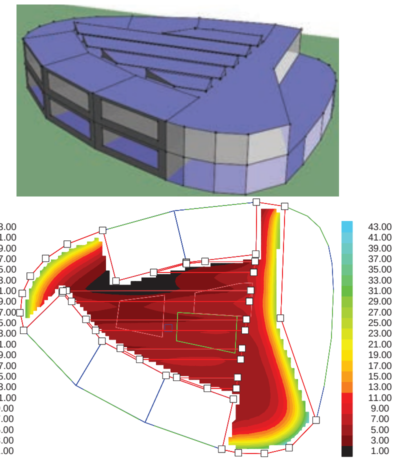
Ill. 5.33 *Daylight - skylight with a void*

	No skylight	Perimeter to the north	Perimeter glass all over	Perimeter with void	Triangles every 0,5m	Triangles every 2m
Daylight factor						
Min.	0,4	0,8	2,6	3,1	1,1	0,9
Average	6,9	7,9	9,8	10,8	11,9	9,5
Max.	43,0	43,0	43,0	43,1	43,6	43,3
Overheating hours						
1st floor						
>26	55	45	79	107	87	64
>27	19	13	35	43	31	21
Ground floor						
>26	16	25	29	27	26	16
>27	4	7	8	7	7	3

Ill. 5.34 *Skylights investigation*



Ill. 5.35 Daylight - triangles every 0,5m



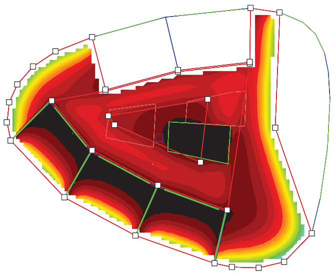
Ill. 5.36 Daylight - triangles every 2m

SKYLIGHTS

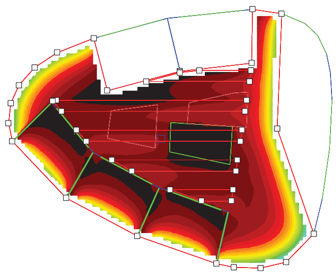
The results from skylight investigation shows to the left the degree of reduction of overheating hours due to different skylights compared to the model with no skylights.

Skylight with a void in the middle demonstrates the best performance in terms of daylight, raising the minimum value of daylight factor up to 3,1% in the darkest spot. However, it results in the biggest amount of overheating hours.

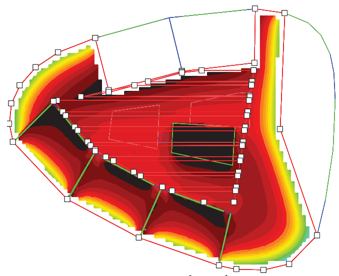
In terms of distributing daylight evenly, the triangle skylights work very efficiently by giving light all over the shared space. Although it adds up some overheating hours.



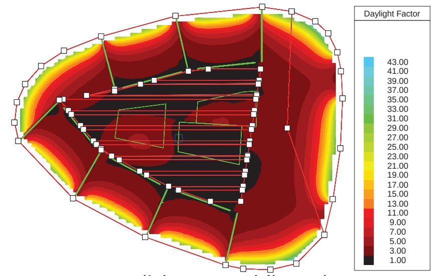
Ill. 5.37 *Perimeter skylight with a void*



Ill. 5.38 *Triangles every 2m*



Ill. 5.39 *Triangles every 0,5m*



Ill. 5.40 *Daylight - ground floor plan*

CLASSROOMS

An early investigation showed a lack of daylight deep in the room in the classrooms, where next to the inner wall only 1% of daylight factor was detected. Therefore a research of impact from skylights to the classrooms is performed.

The inner walls between the classrooms and shared areas are given a horisontal glass ribbon of a size of 1 meter high to investigate how much light it can bring in to the room.

The results above indicate that the triangle skylights every 0,5 meter bring in the most of daylight in the classrooms thus eliminating a contrast between very bright shared areas and dimmer classrooms.

The 'perimeter' skylight has almost no impact on the daylight in the classrooms although it enables more even distribution of light in the common space.

After evaluating pros and cons of different skylights, the triangle skylights are proven to be working according to its benefit for daylight and relatively limited overheating hours. More over, due to its orientation to the North, the South side surfaces of the skylights might be used for solar cells if it is needed.

GROUND FLOOR

The ground floor shared area is found as being the most critical room. Thus an impact from the 1st floor skylights must be checked.

On the illustration above the ground floor plan is shown indicating how much light it gets through the holes in the floor from the 1st level.

The results show that working areas on the ground level get enough daylight where the minimum value is 2%, average 7,2% and the maximum 42,3% of daylight factor.


Skylights
Skylights
Skylights
Skylights

THERMAL COMFORT

INTRODUCTION

In this section rooms will be investigated in terms of thermal comfort, pollution and ventilation effectiveness. District B has been chosen as the most critical in terms of overheating risk due to the large number of classrooms towards the South and great glazing area in the shared spaces.

Indoor climate conditions will be checked in two different rooms – the classroom towards the South and the shared area on the first level (ill. 5.41, 5.42).

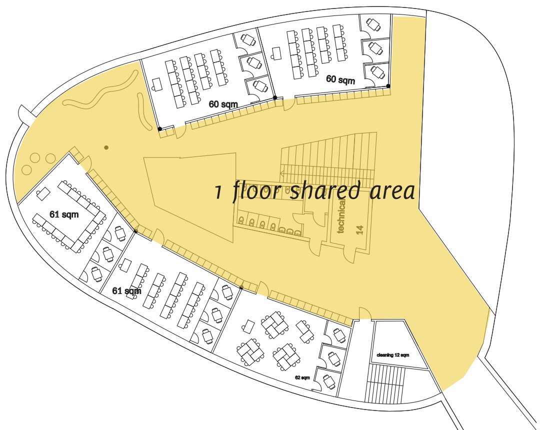
The iterative process of modifications of settings and derived results will be described according to following parameters – temperature, humidity and CO2 level and visually demonstrated in graphs and tables. The main focus is on temperature and CO2 concentration which are usually the most important factors of dissatisfied users in schools due to high internal loads.

As a starting point for construction, U-values were taken from BR10, whereas air changes have been calculated manually. The results according to sensory pollution are being used.

Since the annual graphs only give an overall performance of the year, it is imperative to take a closer look to the occupancy hours and critical days with the highest peak in temperature. Critical days might change from simulation to simulation.

The results of relative humidity are also given, although the VE does not handle a humidity from people, thus the final results cannot be considered as fully correct.

The starting and the final values and results will be shown while the iteration process will be only described by emphasizing changes in settings according to particular issue.



Ill. 5.41 First floor plan

Ill. 5.42 Ground floor plan

INPUT IN VE

Physical measures of the district:
Groundfloor
› 5 classrooms of 60m2:
›› 3 classrooms to the South
›› 2 classrooms to the North
› shared area of 767m2

1st floor
› 5 classrooms of 60 m2:
›› 3 classrooms to the South
›› 2 classrooms to the North
› shared area of 622m2

Glazing area:
› Classrooms - 35% of floor area – 8,7x2,4m window
› Ground floor shared area – 229 m2 – 30% of floor area ratio
› First floor shared area – 260 m2 – 40% of floor area ratio
› 1 floor – triangle skylights – 130m2

Internal heat loads (worst case):
› Classrooms – 28 pupils of 54w, 1 teacher of 90W
› Shared areas – 130 pupils of 54W
› Equipment – 4W/m2
› Occupancy time: 8:30-17:00

Construction (BR 10):
External walls U=0,3
Partitions U=1,7
Ground slab U=0,2
Roof U=0,2
Floor/ceiling U=0,5
Windows U=1,8, G=0,64

Heating
› 21 c° on continuosly during heating season (Jan 1-Apr 30 / Oct 1-Dec 31)

SOUTH CLASSROOM

STARTING INPUT

Physical measures of the room:

› 1 classrooms of 60m2:
Glazing area:
› 35% of floor area ratio – 8,7x2,4m window

Internal heat loads (worst case):
› Classrooms – 28 pupils of 54w, 1 teacher of 90W
› Equipment – 4W/m2
› Occupancy time: 8:30-17:00

Thermal conditions:
Mechanical ventilation:
› 8,27 h^{-1} on continuously during occupancy time;
› unoccupied time – 0,35 l/s/m2;
› infiltration: 0,13 l/s/m2, 0,09 l/s/m2 when not occupied;
› supplied air temperature – 20C°;

ISSUE

The annual temperature graph (ill. 5.45) is given to show the overall performance of the room. The required operative temperatures are marked in yellow lines as well as the critical days. The highest peak in the temperature is detected on the 10th of June whereas a drop bellow the limit is seen in the end of September.

When zooming in on the hottest day in June (ill. 5.47) one can see that the temperature exceeds the limit of the operative summer temperature. The line gives a jump in the end of the day, showing that the ventilation system works inefficiently although it is set to work during occupancy hours.

The drop below 21 degrees occurs in the end of September during unoccupied time (ill. 5.48), thus does not require closer attention.

However, very high temperatures are detected before and just right after occupying hours meaning a need of night-time cooling.

A great variation in temperature values during the occupancy time is detected, thus not fullfiling the demand of 2 C° difference.

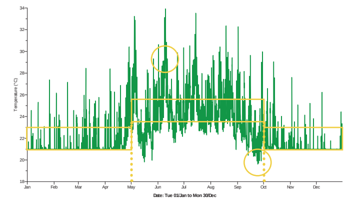
HUMIDITY

The humidity graph indicates many hours below 20% in the winter time as well as above 50% in the summer time due to high external humidity. As previously mentioned, VE does not handle a humidity produced by people.

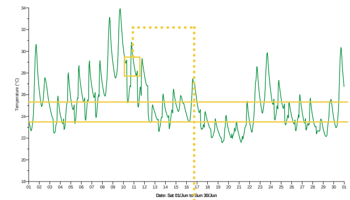
CO_2 LEVEL

CO_2 concentration in the room does not exceed the limit by holding 428ppm value at the peak.

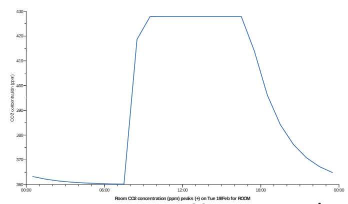
Following, the itterative process will be described as well as derived results shown.



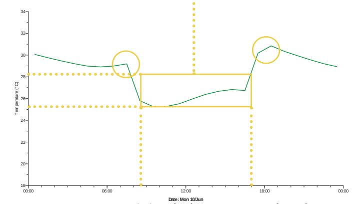
Ill. 5.45 *Annual temperature*



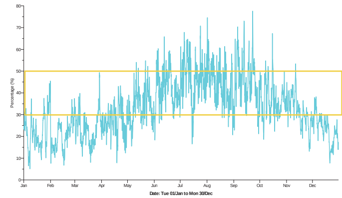
Ill. 5.46 *Temperature in June*



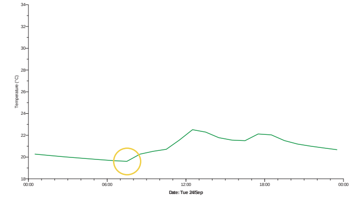
Ill. 5.43 *Room CO_2 concentration*



Ill. 5.47 *Critical day on 10th of June*



Ill.5.44 *Annual humidity level*



Ill. 5.48 *Temperature on 24th of September*

2nd Simulation

In order to avoid a risk of draft, the ventilation rate is lowered to $7h^{-1}$.
Due to overheating hours above 26 C°, the room is given a 1m overhang.
Night-time cooling of 1l/s/m2 is introduced from May to September in order to lower the temperatures during the night and reduce the load of ventilation system before the occupancy.

Seen from the chart below, all the changes are working in terms of reducing over- and undertemperatures in summer, likewise - in winter.

3rd Simulation

Ventilation working period is extended one hour before and after occupancy – 7:30-18:00.

Supplied air temp. in summer is raised to 22 C° due to many hours below 23,5 degrees. In winter it is reduced to 19C° due to many hours above 23C°.

Solar shading – curtain net with a shading factor of 0,76 is applied during occupancy.

U values are being lowered to: walls U=0,12, windows U=0,89, G=0,6, ground slab - 0,07.

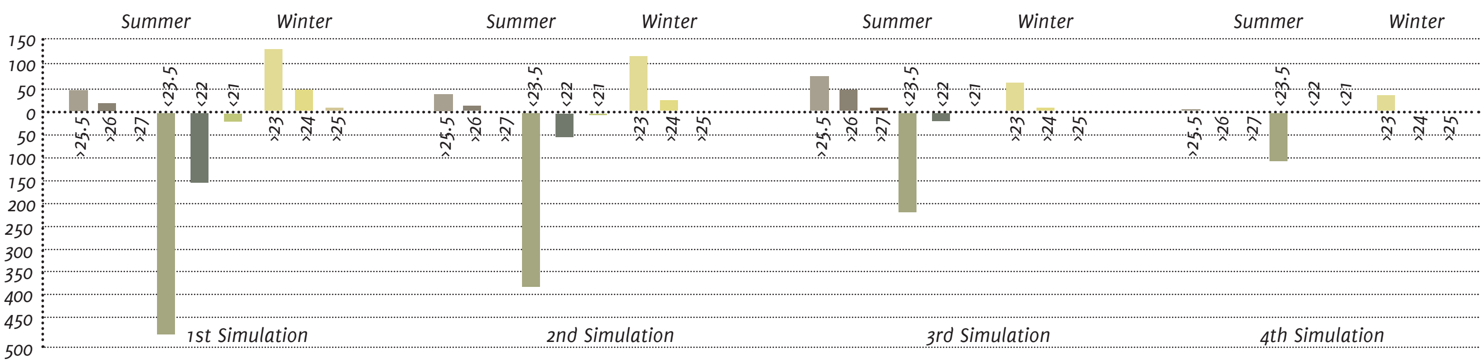
The results indicate that solar shading decreases hours of overtemperature during the winter time and undertemperature during summer. Though in summer time overheating increases.

4th Simulation

Air change rate is reduced to $6,5h^{-1}$.
Mechanical ventilation when building is not occupied is increased to 1l/s/m2. Although it eliminates the overheating in summer, this is not enough to solve the issue with hours below 23,5C°.

Temperature control censors are applied during summer – supplied air temperature reduced to 21 C° and 25 C° air is supplied whenever temperature drops below 23,5C°.

The final results and graphs are described and shown following.



Ill. 5.49 *Temperature values*

FINAL INPUT

Construction:
External walls U=0,12 W/m2K
Partitions U=1,7 W/m2K
Ground slab U=0,07 W/m2K
Roof U=0,07 W/m2K
Floor/ceiling U=0,5 W/m2K
Windows – Low-e triple glaze with net U=0,89 W/m2K, G=0,58

Thermal conditions:
Mechanical ventilation:
› 6,5 h^{-1} on continuously during occupancy time;
› unoccupied time – 1 l/s/m2;
› infiltration: 0,13 l/s/m2, 0,09 l/s/m2 when not occupied;
› Night-time natural ventilation - 1 l/s/m2 from May to Sept;
› supplied air temp.:
Summer – 21C° + 4C° if temp. in the rooms is less than 23,5C°;
Winter – 19C°;

Solar shading:
Curtain net with shading coefficient of 0,76

Heating:
21 C° on continuosly during heating season;

FINAL RESULTS

All the highest peaks present on the annual graph happen during the night time, thus do not require special investigation.

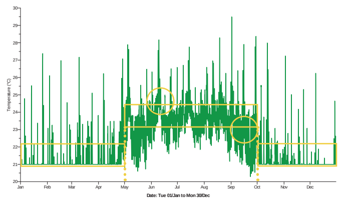
Overheating during summer months do not happen but in May and September there are quite many hours below the operative temperature.

September is shown on illustrations 5.53, 5.54 as the one with the biggest amount of hours under operative temperature of 23,5C°. The performance of a critical day indicates that most of the day temperature is under 23,5C° though it stays stable and changes only half of a degree.

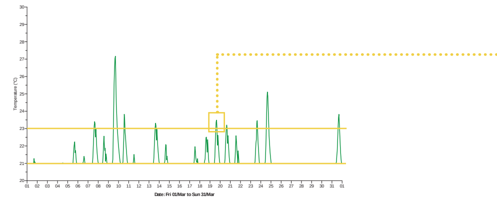
The table on the right (Ill. 5.56) shows that during March some overtemperature occur. Though the ill. 5.52 displays that the temperature rises only half of a degree above 23C° at the most.

However, temperature during winter months never rises above 24C°.

The graphs indicate that the temperature is being kept under the difference of 2 degrees most of the time during occupancy.



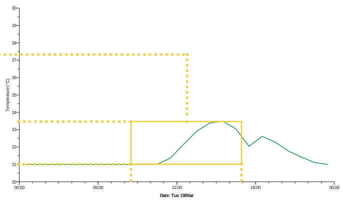
Ill. 5.50 *Annual temperature*



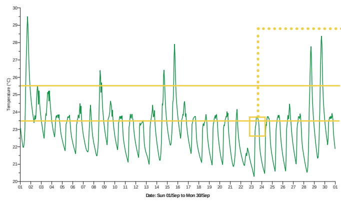
Ill. 5.51 *Temperature in March*

CO_2 level stays quite low, under the limit of 810ppm (ill. 5.55).

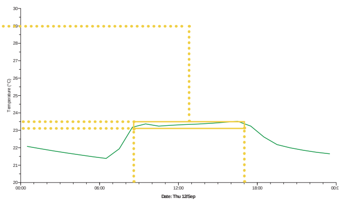
Table on the right (Ill. 5.56) shows the results in all three parameters – temperature, humidity and CO_2 level. Average and maximum values are given to get an understanding of the average and the worst performance of the room.



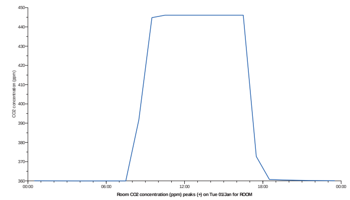
Ill. 5.52 *Critical day on 19th of March*



Ill. 5.53 *Temperature in September*



Ill. 5.54 *Temperature on 12th of September*



Ill. 5.55 *CO2 concentration*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor temperature,C°												
Average temperature	21,02	21,10	21,25	21,77	23,80	24,81	-	24,54	23,56	21,51	21,23	21,09
Max. temperature	22,17	23,29	23,49	23,75	25,58	26,05	-	25,68	26,01	23,74	23,08	22,63
Temperature in summer, C°												
Hours >25.5C°	-	-	-	-	0	0	-	0	1	-	-	-
Hours <23.5C°	-	-	-	-	37	11	-	8	54	-	-	-
Hours <22C°	-	-	-		0	0	-	0	0	-	-	-
Temperature in winter, C°												
Hours >23C°	0	5	10	5	-	-	-	-	-	10	1	0
Hours <21C°	0	0	0	0	-	-	-	-	-	0	0	0
Air humidity, %												
Average	22,37	20,36	23,18	28,03	34,53	44,75	-	44,76	45,55	37,42	31,79	23,44
Max.	45,76	37,68	49,99	35,44	47,28	65,86	-	57,85	67,94	70,24	53,60	31,19
CO2 level, ppm												
Max	446	446	446	446	446	446	-	446	446	446	446	446
Average	383	382	381	382	383	380	-	382	381	383	381	381

Ill. 5.56 *Indoor climate*

SHARED AREA

STARTING INPUT

Construction:
External walls U=0,12 W/m2K
Partitions U=1,7 W/m2K
Ground slab U=0,07 W/m2K
Roof U=0,07 W/m2K
Floor/ceiling U=0,5 W/m2K
Windows - Low-e triple glaze with net U=0,89 W/m2K, G=0,58

Glazing area:
›First floor shared area - 260 m2 - 40% of floor area ratio;
›Triangle skylights - 130m2;

Internal heat loads (worst case):
›130 pupils of 54W;
›Equipment - 4W/m2;
›Occupancy time: 8:30-17:00;

Thermal conditions:
Mechanical ventilation:
›6,5 h^{-1} on continuously during occupancy time;
›unoccupied time - 0,35 l/s/m2;
›infiltration: 0,13 l/s/m2 when occupied, 0,09 l/s/m2 when not occupied;
›Night-time natural ventilation - 0,35 l/s/m2 from May to middle of Sept;
› supplied air temp - 20C°;

Heating:
21 C° on continuosly during heating season (Jan 1 - May 14 / Oct 1 - Dec 31)

ISSUE

The annual temperature graph (ill. 5.57) indicates the critical peaks in June and drops in May and September. These peaks are presented more detailed under monthly and dayly temperature performance.

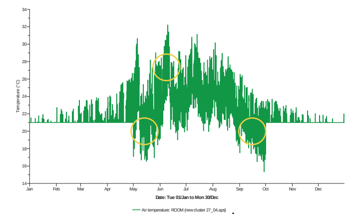
From the graph of 24th of September (ill. 5.60) it is seen that the biggest drops in temperature occur during the night time, thus it is not analysed.

The monthly graph of June and the hottest day on 10th indicate overheating (ill. 5.58, 5.59). Another problem is that the temperature before occupancy rises very high, thus pupils start classes in a very hot room.

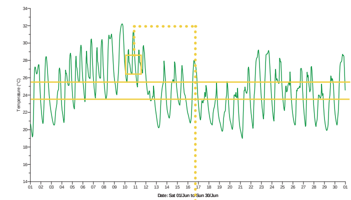
The results from the 1st simulation indicate high risk of overheating in summer time, as well as many hours below the operative temperature, where it drops even below 20 degrees. By this creating a great difference in temperature which should preferably be avoided.

In the winter time overtemperature occurs also. This is related to a very big area of glass facade together with the triangle skylights.

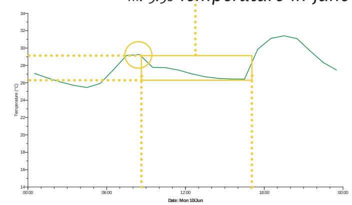
Following the modifications and iterative process will be described.



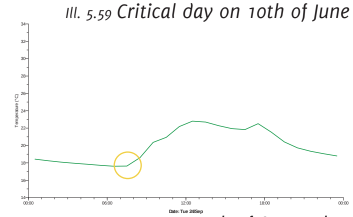
Ill. 5.57 Annual temperature



Ill. 5.58 Temperature in June



Ill. 5.59 Critical day on 10th of June



Ill. 5.60 Temperature on 24th of September

2nd Simulation

Main problems with overheating are detected in May and June, whereas August and September perform much better by having only a problem of undertemperatures.

By increasing air change rate to $7h^{-1}$ and giving the windows a lower U value of 0,89 the problems are not solved and overheating even increases. However the temperature below 23,5C° has been reduced.

The reason for such high number of undertemperature is shown on the ill. 5.60 where after night cooling the temperature is very low, reaching 18C° and it takes some time for ventilation system to heat up the room. Therefore ventilation is set to start one hour before occupancy and night cooling is set only until the middle of September.

Supplied air for the summer months is set to 21C° and in winter - 19C° thus trying to reduce high temperature.

All the changes give benefit only on undertemperature issue yet even increasing overheating problem.

3rd Simulation

To reduce overheating, curtain net is applied for solar shading during occupancy hours and mechanical ventilation is set to start two hours before the occupancy.

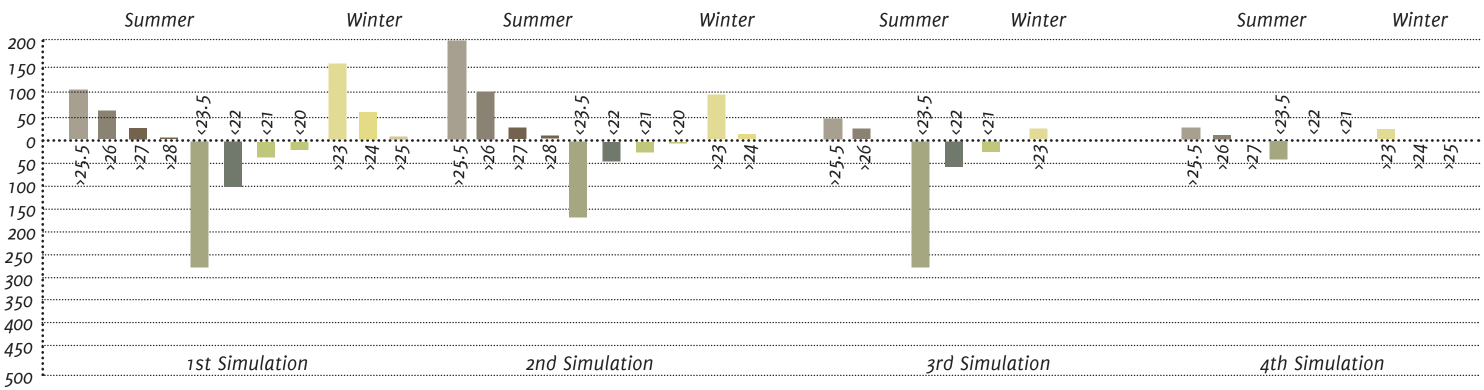
While shading helps to cope with high temperature, undertemperature below 23,5C° is being increased.

4th Simulation

A lower G value of 0,5 is given to the skylights. However, this makes only a small change.

Mechanical ventilation rate for the unoccupied period is increased to 1l/s/m2 which leads to greatly reduced hours for the undertemperatures since it preheats the air before occupancy.

Temperature censors are applied for the summer, when temp. drops below 23,5C° the air of 25C° will be supplied to the room.



Ill. 5.61 Temperature values

FINAL INPUT

Construction:
External walls U=0,12 W/m2K
Partitions U=1,7 W/m2K
Ground slab U=0,07 W/m2K
Roof U=0,07 W/m2K
Floor/ceiling U=0,5 W/m2K
Windows - Low-e triple glaze with net U=0,89 W/m2K, G=0,58
Skylights - Low-e triple glaze with net U=0,89 W/m2K, G=0,50

Glazing area:
›First floor shared area - 260 m2 - 40% of floor area ratio;
›Triangle skylights;

Internal heat loads (worst case):
›130 pupils of 54W;
›Equipment - 4W/m2;
›Occupancy time: 8:30-17:00;

Thermal conditions:
Mechanical ventilation:
›7,5 h^{-1} on continuosly during occupancy time;
›1 l/s/m2 - when not unoccupied;
›infiltration: 0,13 l/s/m2 when occupied, 0,09 l/s/m2 when not occupied;
›Night-time natural ventilation - 1 l/s/m2 from May to middle of Sept;
›supplied air temp.:
Summer - 21C° and 25C° when temperature drops below 23,5C°;
Winter - 19C°;

Solar shading:
Curtain net with shading coefficient of 0,76

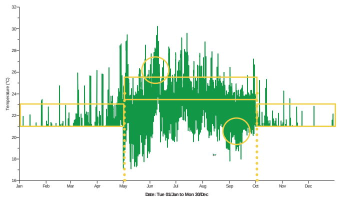
Heating:
21 C° on continuosly during heating season (Jan 1 - May 14 / Oct 1 - Dec 31)

RESULTS

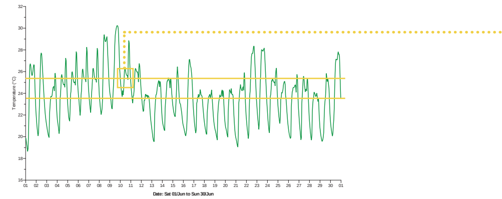
The annual temperature graph (ill. 5.62) presents where critical months and days appear. These peaks are presented more detailed under monthly and dayly temperature performance.

The biggest drops in temperature occur during night, thus is not analysed.

Two months - May and June are seen as the worst cases where the curve reaches the highest temperatures.



Ill. 5.62 *Annual temperature*



Ill. 5.63 *Temperature in June*

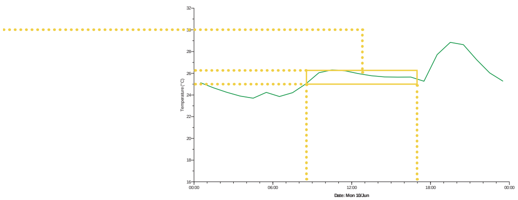
The monthly graphs show that the biggest peaks happen during the weekends. Whereas when looking into weekdays, a break in curve is present showing where occupancy hours end and the ventilation system starts work at a lower rate.

The hottest day in the year is 10th of June and this is the only time where the temperature reaches 26 degrees (ill. 5.64).

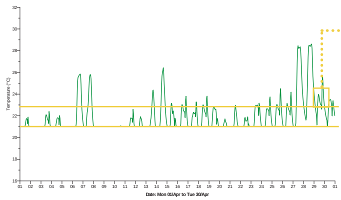
Another critical month is April which has the most overtemperature hours. However, it rises only 1 degree above the operative temperature (ill. 5.65, 5.66).

CO_2 level indicates good results of 435ppm at the maximum (ill. 5.67).

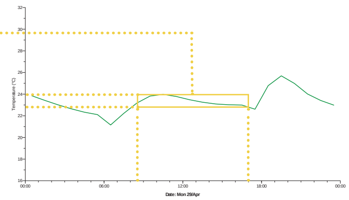
The table on the right presents mean and max values in evaluation criteria showing that in terms of temperature there is only few hours of under- and overtemperature which is perceived as acceptable.



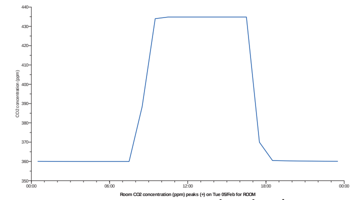
Ill. 5.64 *Critical day on 10th of June*



Ill. 5.65 *Temperature in April*



Ill. 5.66 *Critical day on 29th of April*



Ill. 5.67 *CO2 concentration in the room*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indoor temperature,C°												
Average temperature	21,05	21,10	21,38	21,98	22,54	23,81	-	22,94	22,36	21,23	21,07	21,02
Max. temperature	21,05	22,26	22,36	23,51	25,15	26,72	-	25,18	24,99	22,37	21,64	21,01
Temperature in summer, C°												
Hours >25.5C°	-	-	-	-	2	31	-	0	0	-	-	-
Hours >26C°	-	-	-	-	0	13	-	0	0	-	-	-
Hours <23.5C°	-	-	-	-	8	6	-	5	21	-	-	-
Temperature in winter, C°												
Hours >23C°	0	0	0	22	-	-	-	-	-	0	0	0
Hours <21C°	0	0	0	0	-	-	-	-	-	0	0	0
Air humidity, %												
Average	22,55	20,45	23,07	26,98	34,74	42,63	-	44,89	45,48	37,68	31,89	23,45
Max.	45,55	37,52	49,27	35,28	41,82	59,21	-	48,69	54,53	69,31	53,47	37,93
CO2 level, ppm												
Max	435	435	435	435	435	435	-	435	435	435	435	435
Average	380	379	378	379	380	380	-	378	380	379	379	380

Ill. 5.68 *Indoor climate*

INDOOR CLIMATE - RESULTS

In order to evaluate and confirm the quality of the indoor climate, the classrooms and the shared areas have been checked for the thermal comfort and daylight quality. The results for daylight factor, air humidity, temperature and pollution are shown and explained in graphs, tables and illustrations. As previously mentioned the project aims for category A.

DAYLIGHT

In the daylight quality investigation working areas have been analyzed in order to ensure good daylight conditions.

The results indicate that the daylight factor of 2% has been reached in most of the areas by employing skylights in the shared areas and applying a glass ribbon for the inner walls in order to lead the light deeper into the rooms.

OVERHEATING

Overheating is the most common problem-causing parameter in schools mostly at the end of heating season in April and in the beginning of summer in June. Thus the goal was to prove that high temperatures can be coped with.

While this issue has been handled in the south classrooms by applying overhang and curtain net for solar shading, it was necessary to increase the ventilation rate in the shared areas during unoccupied time and start ventilation with full capacity two hours before occupancy.

The aim and the biggest challenge was to keep the temperature difference of 2C° by maintaining operative temperature of 21,0-23,0 C° in winter and 23,5-25,5 C° in the summer time.

The results show that the temperature in the South classrooms most of the time does not exceed the limits, although there are few hours where it drops or rises 1 degree but never more. This comprises less than 10% of the entire occupancy time and is considered acceptable.

However, the balance between under- and overtemperatures on the 1st floor shared area was more difficult to handle. Even after increasing the ventilation rate for unoccupied period and starting the ventilation two hours before occupancy, it still holds few hours over 26C° in June.

However, this comprises only a small percentage of occupancy hours, and can be perceived as acceptable.

HUMIDITY

As mentioned before, the humidity data cannot be considered as correct since the VE does not handle this parameter very well. The results are very low in the winter time which would cause irritation and dryness for the users had they been realistic.

POLLUTION

Another crucial factor when evaluating indoor climate is indoor pollution from people and materials.

The results prove, that CO_2 concentration in both rooms never exceeds the limit and even at the maximum it stays almost at the half of allowed.

VENTILATION

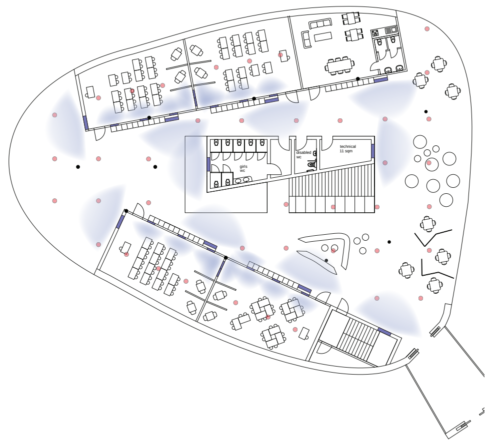
VENTILATION STRATEGY

According to Danish Building Regulations, classrooms in schools must be ventilated mechanically due to high internal gains from pupils in small rooms. Therefore mechanical ventilation will be used all around the year for supplying fresh air to the classrooms and shared areas. The air changes in the building are based on sensory pollution (olf) from manual calculations and simulations from VE.

Natural ventilation is considered as being suplementary when it is needed and for passive night-time cooling during warm period.

MECHANICAL VENTILATION

Displacement ventilation principle is chosen due to following reasons:
› good performance in situations with high internal heat loads
› high efficiency in rooms with high ceilings
› airflow rate and supply air temperature can be adjusted according to the demands



Ill. 5.69 *Layout of ventilation units*

Ill. 5.70 *Ventilation unit - QLF-3*

This applies both to the shared areas of the cluster which have a height of around 7 meters and the classrooms with a height of 3,5m.

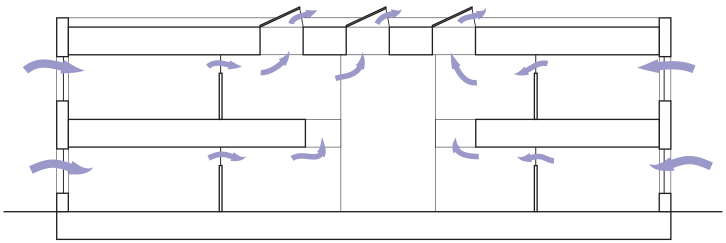
In displacement ventilation air is supplied as close to the floor as possible and exhausted near or in the ceiling. The air, supplied directly into the occupied zone, must be delivered in low velocity and of temperature difference in relation to its surroundings. The air fills the room from the floor and displaces the polluted and hot air towards the ceiling. The extraction point of the exhaust air is located above the occupied zone – preferably close to ceiling level.
The mechanical system uses heat recovery with efficiency of about 85% which will lower the heat demand in the building.

Since cool air is supplied directly to the occupied zone, special attention should be paid to chosing ventilation units with low velocities of the potential draught risk close to the units.

The supply units are embedded in the structure (wall-mounted, covered by a decorative panel), ducts are hidden inside the structure.

Low velocity displacement units Troxtechnik QLF-3 (ill. 5.70) were chosen both for the classrooms and shared areas of the sizes

Ill. 5.71 Ventilation unit and duct installation



Ill. 5.72 District section - natural ventilation

respectively 750x450x185 and 2000x1250x287.

In the classrooms 4 units are to be installed to suply 379 l/s. The capacity of one unit is between 52-157 l/s.

Shared areas would need 10 bigger units to supply 4535 l/s, thus a unit with capacity of 340-1019 l/s were chosen.

A simplified scheme of layouting the units is shown on the illustration 5.69.

The discharge velocities are very low - between 0,1-0,3 m/s which for the category A should be 0,15 m/s in winter and 0,18 m/s in summer. [CR1752, C3.3.2]

NATURAL VENTILATION

To minimize the energy consumption of the building and at the same time ensure acceptable air quality the mechanical ventilation system will be sumpplemented by natural ventilation during the spring, summer and autumn. Also it will be used for night-time cooling to cool down the building before occupancy.

A ventilation strategy of stack principle is applicable for all three districts. This is enabled by having windows both in the exterior walls and long interior windows between the rooms next to the ceiling. Using this principle the air flow from the classrooms would access the shared areas and through the skylights would be withdrawn outside.

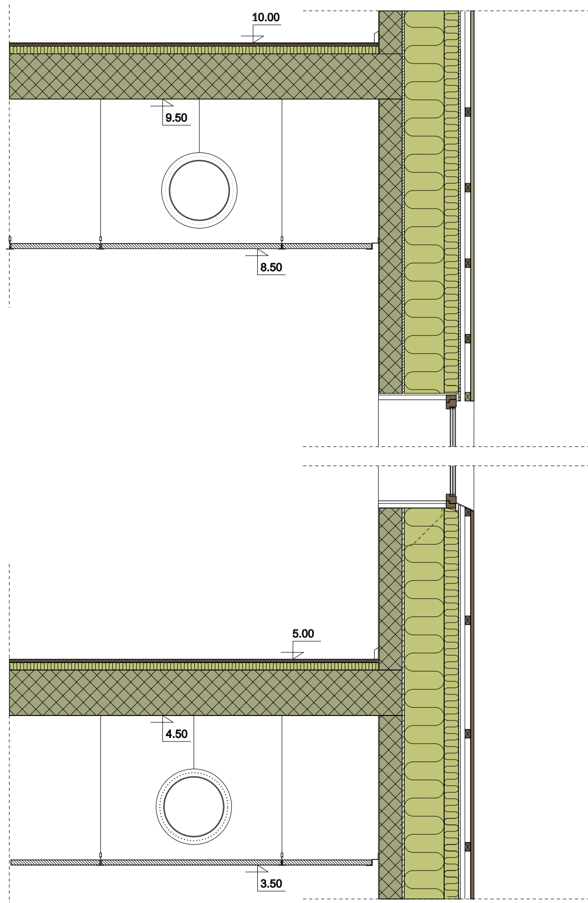
Other rooms in the building might benefit from sigle-sided and cross ventilation where it is possible.

CONSTRUCTION

CONSTRUCTION AND STABILITY

The stresses of the school building are carried by a system of load bearing walls, columns, beams and slabs. To ensure stability the walls around the toilet cores and fire stairs are enforced and serves and carrying and stabilizing structures.

The diagram far right illustrates the load bearing system of the building, where barring walls are represented by grey color, columns – red, beams – brown and slabs – violet.



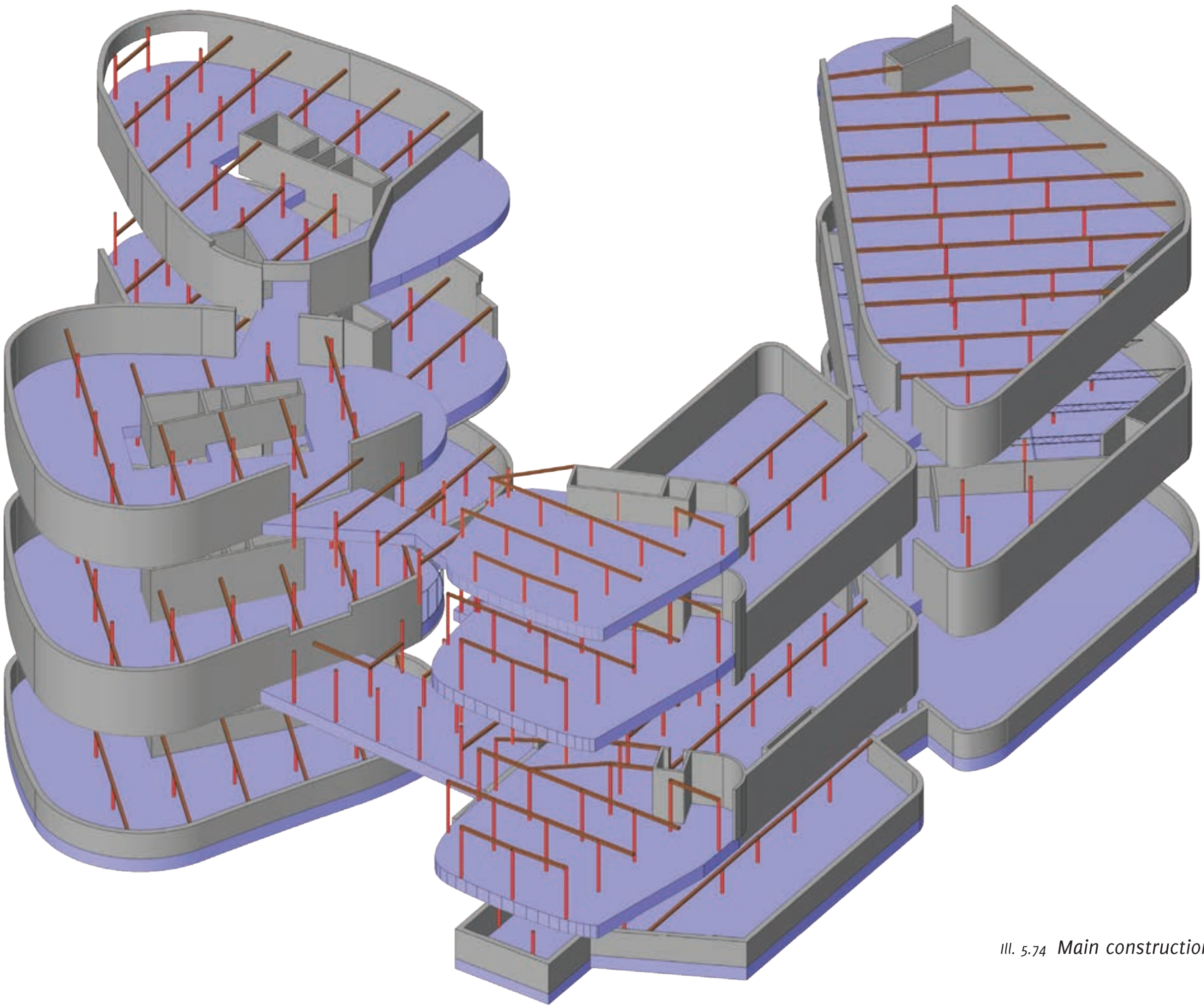
Ill. 5.73 *Detail of wall and floor, scale 1:50*

SECTION OF THE WALL

- Concrete 150 mm
- OSB 15 mm
- Insulation 265
- Insulation 95 mm
- Winboard 12 mm
- Hollow space 30 mm
- Laths 50x40 mm
- Wooden panels 22 mm thick

SECTION OF THE FLOOR

- Wooden floor
- Insulation 50 mm
- Concrete 300 mm
- Hollow space for ventilation installations1000 mm
- Troldtekt panels



Ill. 5.74 *Main construction*

FACADES

While sketching the facades, the building of school was divided into two parts: the more massive volume for classrooms, and transparent volume of the public building in the corner. The corridors that connect clusters and the main entrance were also assigned as the transparent volumes.

VOLUMES OF DISTRICTS

Wood cladding was chosen for districts A, B and C. Two versions of horizontal and vertical cladding were sketched. Because of the practical reasons the horizontal cladding was rejected – since the volumes are curved it would be more difficult to clad them. Also the vertical cladding creates an illusion of lighter and higher volumes then they actually are.

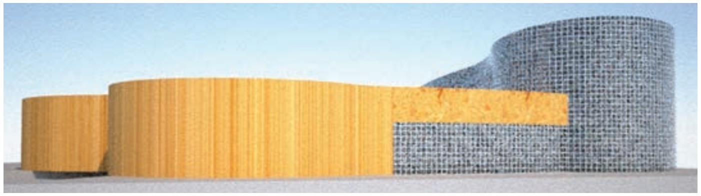
A discussion whether or not to emphasize the decks was taken. After sketching it was noticed that emphasizing of decks messes the overall picture of solid wooden volumes.

The light investigations showed that a big percentage of glass was needed to guarantee good daylight conditions. This left very little options to play with windows placement. The windows were cut as the continuous holes almost around the whole perimeter of the districts A, B and C. Slender 40 centimeter wide colored wooden panels divided the windows into smaller sections. The wooden panels are placed with different gaps between each other and create playful expression.

PUBLIC VOLUME

Since the public building should signal the passersby that it is a place opened not only for school staff, but for the residents and guest of the area it was made transparent, open and clear by using a lot of glass. In this volume the decks are emphasized.

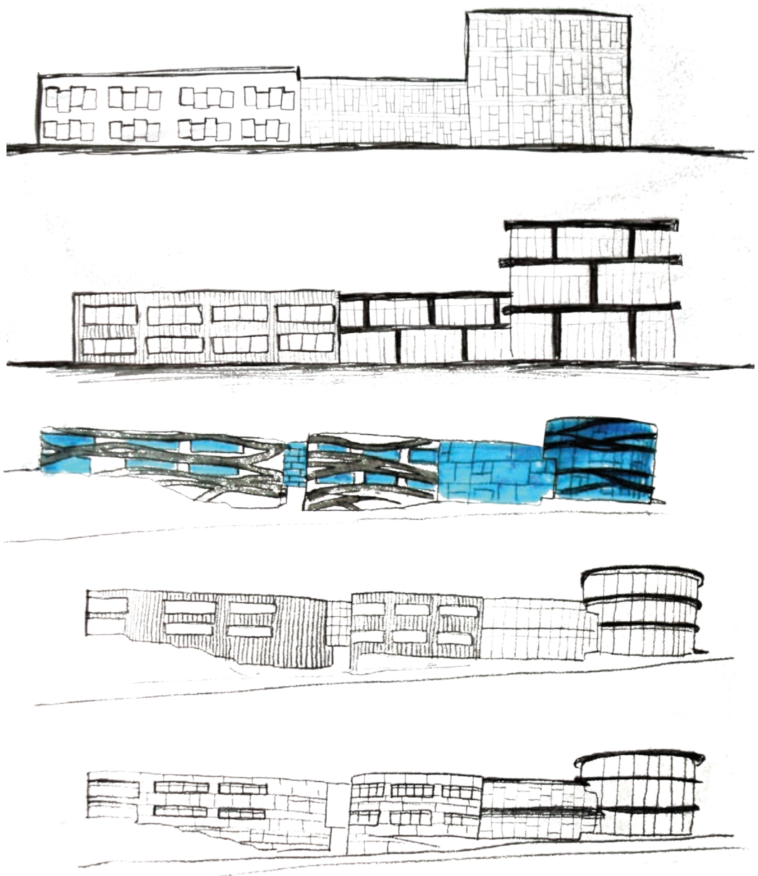
The windows are slightly tinted and have a low "g" value in order to solve the problem of the overheating. The overhangs help to deal with this issue as well. They are 1 meter in length, attached on the south facade on all 3 levels of the volume. The overhangs are made more massive and look as the continuation of the decks.



Ill. 5.75 The overall idea of the fasades: massive volumes of dirtcits and glass volume of the public building

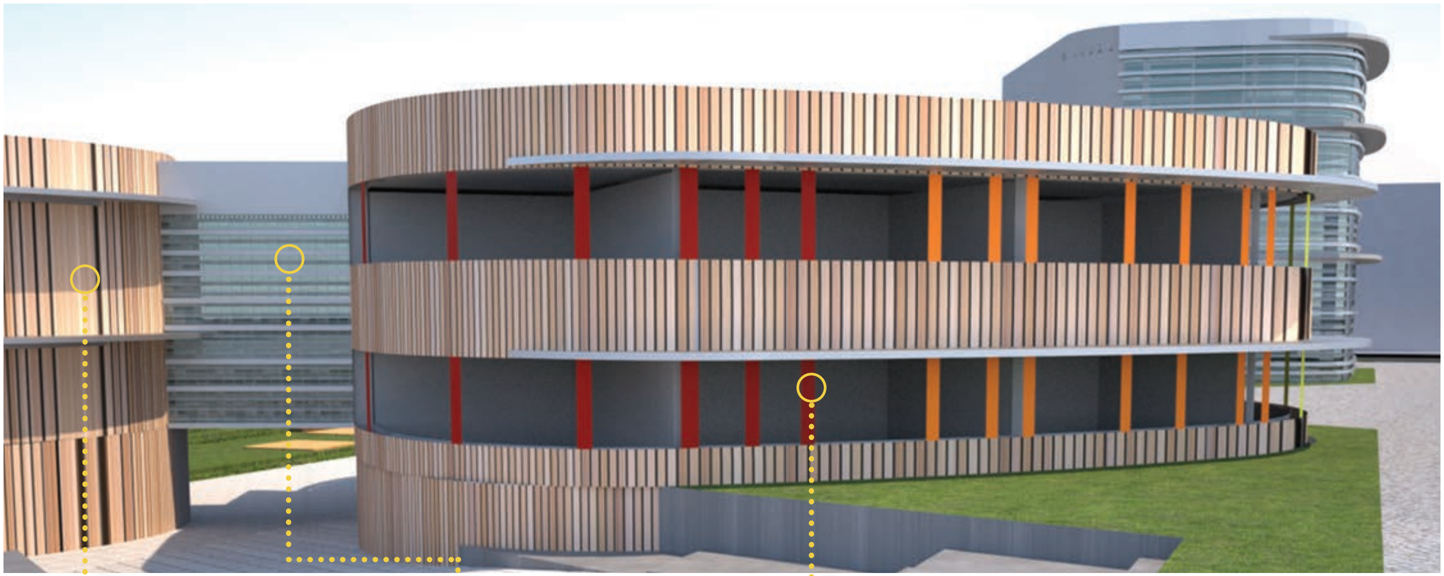
Ill. 5.76 Vertical panelling

Ill. 5.77 Emphasized decks on the volumes of districts



Ill.5.78 *Various sketches of the fasades*

MATERIALS



Ill. 5.79 *Exterior materials*

FACADES

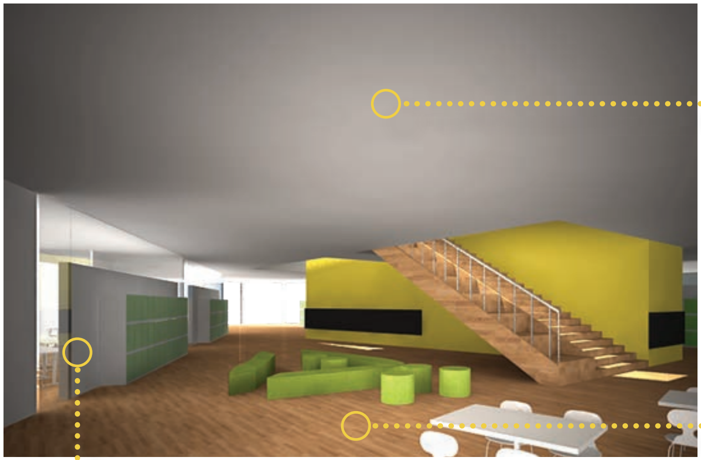
Wooden vertical birch cladding is used on the facades of the districts to emphasize its soft curved forms. It also brings a nice contrast to the brick facade buildings in the context. In relation to interior, it speaks nicely with the materials used inside - wooden flooring in the classrooms and shared areas.

CURTAIN WALLS

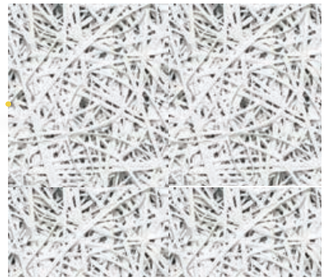
Tinted glass curtain walls with horizontal shading elements are used for the public and transit parts of the building.

WINDOW PARTITIONS

Wooden colored panels are used for window divisions.



Ill. 5.80 *Interior materials*



Ill. 5.81 Troldtekt acoustic panels

Ill. 5.82 Wooden floor

Ill. 5.83 White plaster

CEILING

Troldtekt acoustic panels were chosen for the ceiling due to its excellent sound absorption performance.
The panels are being used both in classrooms and shared areas.
It should be of white color in order to reflect the light and keep the rooms bright.

FLOOR AND STAIRS

In order to keep cosy atmosphere and benefit from acoustic qualities, hardwood flooring was chosen both for the floor and stairs. Maple was picked for its wear resistance and practicality. This type of flooring is often used in bowling alleys or sports floor.

WALLS

All walls are plastered white to provide better utilisation of daylight and make rooms as bright as possible.
The inner core is plastered yellow, to bring playfull and lively atmosphere to common spaces.

ENERGY

ENERGY FRAME

To investigate whether the school building meets the energy frame of the Building Regulations 2010, the calculation program Be10 is used. As shown in the illustration 5.84 the building's energy needs must be less than 71.4 kWh / m2 / year. However with supplement for special conditions this number rises to 80,9 kWh/m2 / year. The energy frame of the school building is calculated to be 72.8 kWh / m2 / year, which means that the requirements for 2010 are met.

Be10 is configured with values that are assumed to reflect the use of the building, which means that the model represents a practically realistic building. However, the model is simplified because of the building's size and complexity. (See table for ventilation zones.) Key figures and a model of the Be10 calculation can be found on the enclosed disc.

To achieve an energy frame equal to 2015 it is necessary to lower consumption for both heating and ventilation. Consumption can be further reduced by using for example solar cells, which can be mounted on the skylights facing south with a 45 degree angle.

Standard:	**71,4 kWh/m2 year**
Supplement for special conditions:	**9,5 kWh/m2 year**
Goal: total energy frame with supplement:	**80,9 kWh/m2 year**
Result: energy frame for the School building:	**72,8 kWh/m2 year**

PEOPLE DISTRIBUTION

850 pupils:
›classrooms - 450
›subject rooms - 70
›shared areas - 150
›sports hall - 30
›library - 50
›canteen - 50
›auditorium - 50

50 staff:
›classrooms - 20
›staff rooms - 10
›offices - 12
›fitness - 5
kitchen - 3

NAME OF ROOM	AREA, m2	ROOM HEIGHT,m	ROOM VOLUME,m3	AVERAGE PEOPLE LOAD	VENTILATION RATE (sensory pollution), l/s/m2	AIRCHANGE (sensory pollution), h^{-1}
Classroom [grade 0-3]	80	3,5	280	0,18	*3,71*	*3,82*
Classroom [grade 4-6/7-9]	60	3,5	210	0,25	*4,72*	*4,86*
Subject room	90	3,5	315	0,16	*3,42*	*3,52*
Shared areas	600	3,5	2100	0,04	*1,69*	*1,74*
Sports hall	984	6	5904	0,03	*4,44*	*2,67*
Fitness	130	3,5	455	0,04	*5,33*	*5,49*
Changing rooms (teachers)	75	3,5	262	0,06	*1,78*	*1,83*
Changing rooms (pupils)	75	3,5	262	0,4	*6,89*	*7,09*
Canteen	440	7	3080	0,11	*2,70*	*1,39*
Library	400	7	2800	0,12	*2,92*	*1,50*
Auditorium	210	5	1050	0,23	*4,43*	*3,19*
Offices	18	3,5	63	0,16	*2,89*	*2,97*
Staff room	60	3,5	210	0,08	*2,00*	*2,06*

Ill. 5.84 Required ventilation rates

In order to make energy consumption calculation in BE10, an assumption of average performance of the occupants has been prefigured as listed above. Numbers show how pupils and staff members distributed in the school on a daily life.

This was done to figure out the average ventilation rate for the main functions. Other than mentioned functions are assumed to be corridors, entrances, storage rooms etc. and are given a ventilation rate of 0,35 l/s/m2 from BR10. Toilets and kitchens are given 0,37 l/s/m2 from BE10.

FIRE

CATEGORY

Most of the building is a utilization category 2, which among other things includes classrooms. Cafeteria and auditorium are assembly rooms placing them in utilization category 3. Different utilization categories are not to be in the same fire compartment.

FIRE CELLS AND FIRE SECTIONS

Each of the 4 building volumes constitute a fire compartment. Each compartment is equipped with an Automatic Fire Extinguishing System (ABDL), with self-closing door activating in case of fire. In addition, the emergency exit stairs, installation shafts, ventilation shafts and elevator shafts each constitute a separate fire compartment.

A fire compartment consists of fire cells. Each classrooms will be one fire cell. If a fire cell is max 150 m2 and is designed for max 50 persons, it is enough with either one exit or with only one door to an escape passageway, which in opposite directions leads to two independent exits. For any room it is required that from an arbitrary point in the room there is no more than 25 meters to the nearest escape passageway or exit. That means that there must be a maximum of 50 m between the exits.
Rooms for personal residence are conducted with emergency exits. In case fire there must be at least two options for escape for an adult or child - through the fire staircase or through the rescue opening. [www.ebst.dk]

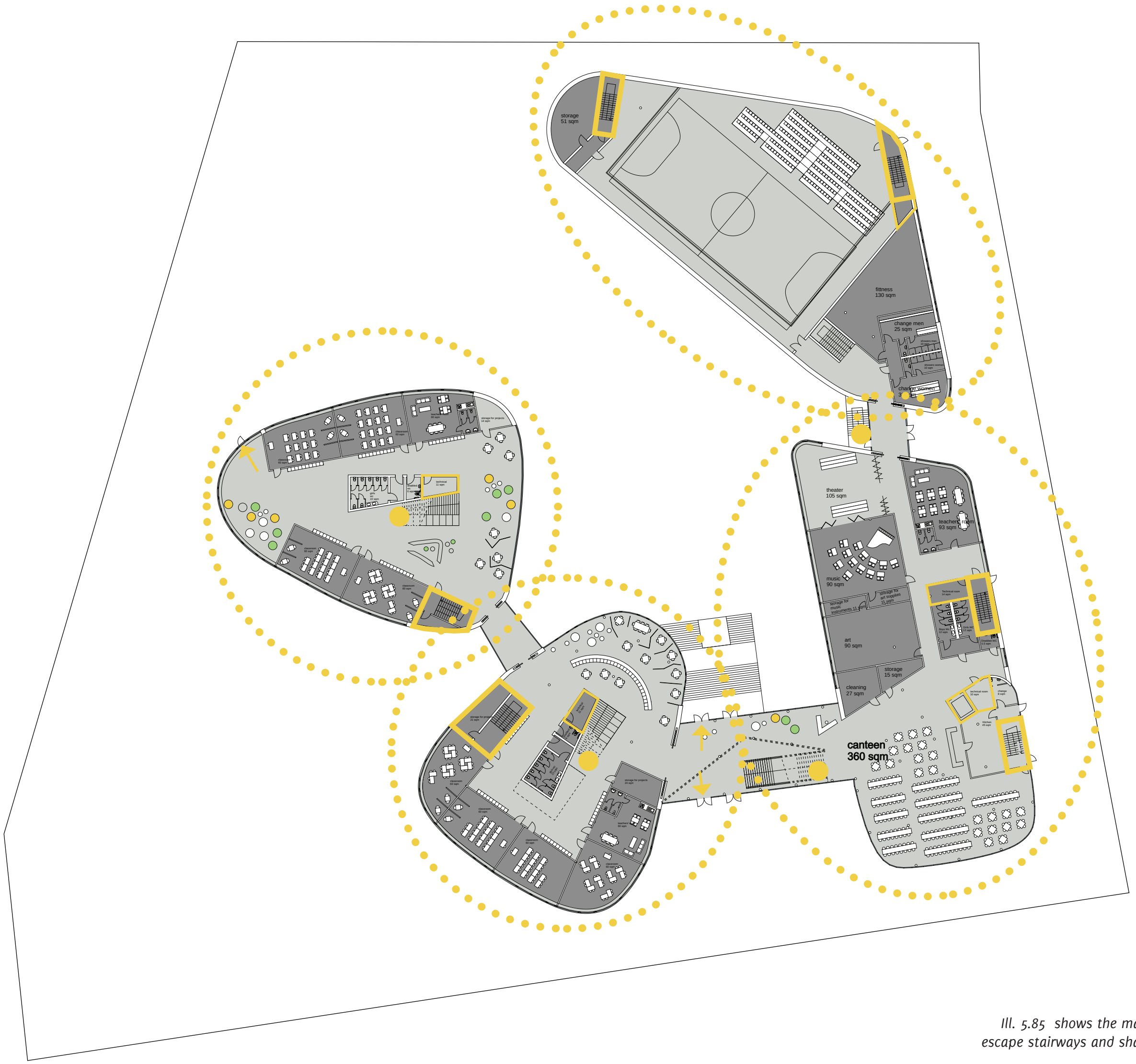
The building must be fitted with sprinklers and equipped with an Automatic sprinkler system (AVS) that is able to alert the user in case of fire.

OUTDOOR AREAS

The outdoor areas must have fire rescue areas located between 4-7 meters from the building. Fire routes to the fire rescue areas must be conducted with a clear width of 2.8 m and a clear height of at least 3.4 m.

These requirements has been incorporated in the preparation of the site plan.

In a case of fire the fire fighters are able to reach the building via Ingerslevs Boulevard and St. Annagade as well as via the ramp that leads toward the inside courtyard.



Ill. 5.85 shows the markings of volumes, escape stairways and shafts as fire sections

OUTRO

PROJECT VIEW

ARCHITECTURE, LANDSCAPE AND INTERIOR

The political vision for the area is a new and modern school building with future-oriented educational and technical solutions and a healthy indoor climate. The building design should be open and inviting, bringing benefit for the school members as well as the residents and guests of the area.

Integration of the school into the city played an important role in the design. In terms of the architecture the building is divided into sections, where premises intended for pupils are placed in 2 storey buildings - as seen from the streets - while the volume for public functions is seen as 3 levels, thus relating to the surroundings in terms of proportions and heights.

The city and school relationship is further expanded by creating a possibility for local residents to use some of the functions, such as canteen, library, auditorium, sports hall and some of the subject rooms. Such premises are shared with the city for the most of the day, but especially in the afternoons – when the classes are over.

The landscape helps "connecting" the school with the city as well. The urban garden, located on the south side of the site and close to the Ingerslevs Boulevard, is accessible to everybody. The currently existing skatepark is an important part of the area's history, and is expanded, upgraded and re-located to the urban garden.

Meanwhile the north side of the site, where the playing garden is placed, has a strong connection with the existing Skolemarken. The young visitors of Skolemarken are welcome to use the activities in the playing garden.

The learning garden, placed in the centre of the building is a more private green space, though it is not completely isolated and can be reached both from the urban and playing gardens. The learning garden is dedicated to pupils and school staff. The goal to create a complex and interesting outdoor space was achieved by terraced landscape, wooden platforms, vegetables gardens, trees and ponds. The intention for the learning garden was not only for it to be used for socializing and relaxing, but also to contribute to the school curriculum. The direct exits from the subject rooms encourage the integration of plants, water and soil for experiments and observation.

Based on the different learning theories of today we chose to divide pupils into 3 age groups with their own district in order to fulfill their different needs better.

The goal of the project was to create a school were almost every single square meter can be used. Even though the classrooms are fixed, they "expand" into the shared areas and the rest of the school when needed. A typical day for children from B and C districts starts with receiving the instructions in the classroom, later they form groups and use group tables in the common areas or if needed go to the library to work individually. Children who need more attention and supervision might stay in the classrooms, close to the teacher. So the different environments correspond to different ages, abilities and needs of pupils.

Flexible furniture is placed in the shared areas. Tables, chairs and movable partition walls can be transformed and moved creating new learning situations. Pupils are able to shape their own space – depending on the size of group and level of privacy. This enables the space to be flexible and easily used for different activities.

Classrooms in the district A are bigger in size because younger pupils need constant supervision from the teachers. They are not going to use shared areas that much and they will spend most of the day inside their home base. Because of this the classrooms of pupils A are more complex in layout. They have an instruction zone, the working zone and the silent zone – a small two storey cabin where they can hide and relax on the soft furniture and bean-bags.

The school building could easily adapt to the changing needs in the future. Since the load bearing system is based mostly on column grid, it means that the classrooms walls can be removed or expanded if needed.

However, a number of challenges had been met through the design process. The first big challenge was creating the room program since the municipality had only a vision of a new school. Although it opened up the opportunities to be more creative, it took quite a long time to investigate room programs of other projects and understand what the new school should contain.

The municipality also had a vision of creating a green roof for the outdoor activities. The idea was not further developed in this project. Instead of placing the green areas up the proposal creates a sunken garden. If developed further, the project could deal with a green roof issue and create a fifth façade, which would strengthen the image of a garden school.

INDOOR CLIMATE

From a technical point of view, the goal of this master thesis was to achieve and ensure the highest category in indoor climate. Daylight and thermal comfort have been two major themes.

This challenged the design in a direction, which may be considered alternative compared to the traditional projects with focus on energy efficiency.

The choice of simulation software fell on Virtual Environment (VE), which is comprehensive building simulation tool that in general can perform the same kind of simulations as Bsim. The highest motivation for investing time to learn this new tool was its compatibility with Revit 2010. Therefore it was expected to carry a fast moving and integrated design process.

At some point it was realized that there was a need to limit ourselves to investigating only one of the districts instead of the entire school due to the many square meters. Especially since it took quite a long time to actually learn how to use this complex software, hence for the early stage of the design process we referred more to our logical sense and knowledge than to technical investigations. Though after understanding how VE worked and how it interpreted simulation results, it was possible to make very detailed simulations.

However, after several attempts to import the model, it was detected, that while importing file from Revit, VE does not read the materials and constructions thus one has to apply those manually in VE. Also all the rooms have to be closed, so it does not read the cut outs in the floors, which was quite important for design of the building. The model needed additional cleaning before the importing, thus it was decided to model the volume in VE directly.

Despite hard time spent on trying to achieve the high quality of indoor climate, it has been very interesting to work within this subject.

Virtual Environment was found as a powerful simulation tool capable of wide spectrum of thermal, solar and daylight analysis, natural ventilation and HVAC simulations. The most relevant for this project was to perform thermal analysis in terms of room temperatures in relation to solar gains and high internal heat loads, as well as ventilation effectiveness and pollution analysis. This was coped quite efficient with and gave desirable results.

Besides thermal analysis, a very important parameter for evaluating indoor environment was daylight quality. This was done by using FlucsDL which enables to calculate point by point illuminance and daylight factors, also to compare the quantity of daylight available with or without the shading or overhangs. This was very handy during the process because the overheating risk in relation to daylight quality was one of the main concerns.

However, the tool does not take into account the influence of materials between different rooms and would not calculate the benefits of glass walls between the rooms. Thus it was needed to merge adjacent rooms and design obstructing elements imitating inner walls with glass edges. This was done as well while investigating influence of skylights from the 1st floor to the ground shared area through the holes in the floor.

In general, learning VE is very valuable experience for understanding complex processes and influence of different parameters on the performance of building and systems design, allowing them to be optimized with regard to comfort criteria and energy use.

ENERGY

The BE10 results showed that the 2010 demands of energy consumptions were fulfilled. Unfortunately energy consumption limit for year 2015 was exceeded. This was due to the larger amount of ventilation installations needed to control indoor climate and fulfill high indoor climate category requirements.

Since the building was so complex and big, the procedure of BE10 calculations was simplified. Maybe if calculations were made with a greater precision – the results would be more favorable. But in general a focus on indoor climate makes reaching low energy consumption a difficult task.

ILLUSTRATIONS LIST

LITERATURE LIST

BOOKS

[Knudstrup, 2004] – Integrated Design process in PBL. In Kolmos et al (red): The Aalborg PBL model - Progress, Diversity and Challanges. Aalborg University Press, Aalborg University

[Knudstrup, 2009] Approaches to the design of sustainable housing with low CO2 emission in Denmark, Renewable Energy 34

[Knudstrup, 2010] – How can we adapt education programmes to the architecture of the future?, Nordisk Arkitekturforskigning nr. 1

[Kirkeby 2006] - Mette Kirkeby: "Skolen finder sted", Statens Byggeforskningsinstitut, Hørsholm, 2006

["Model Programme for public schools" 2010] - Grontmij Carl Bro, Sinal Arkitekter og Mandag Morgen: "Modelprogram for Folkeskoler",Erhvervs- og Byggestyrelsen og Realdania, 2010

REPORTS

["Tomorrow's buildings for children - space for play and learning" 2008] - Aarhus kommune, Born and unge, Linde Tryk, 2008 (CD)

[Consultation Draft 2010] - Aarhus kommune, born and unge, Linde Tryk, 2010 (CD)

[BR10] - SBi-230, Anvisning om Bygningsreglement 2010, Statens Byggeforskningsinstitut, Aalborg Universitet, 2010

[CR1752] - Ventilation for buildings - Design criteria for the indoor environment, CEN report, 1998

[DS/EN 15251] - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing, 2007

[Sunde skoler] - Sunde skoler. Indeklimaforhold i undervisningsrum og institutioner for børn, 2001

[Indoor climate and ventilation of schools] - Indoor climate and ventilation of schools. REHVA workshop report clima, 2007

WEBPAGES

[www.aarhus.dk] - http://www.aarhus.dk/~/media/Dokumenter/MBU/RULL/Midtbyskole/Hoeringsudkast-til-byraadsindstilling-vedr-ny-midtbyskole.ashx

[www.stiften.dk] - http://stiften.dk/apps/pbcs.dll/article?AID=/20081127/AAS/969015368/1003

[gundog.lbl.gov] - http://gundog.lbl.gov/dirpubs/BS05/BS05_0231.pdf

[www.visitaarhus.com] - http://www.visitaarhus.com/international/en-gb/menu/turist/om-aarhus/aarhustoday/aarhustoday.htm

[www.nordarch.dk] - http://www.nordarch.dk/ongoing/skt-annagade-skole-skatepark/

[www.visitaarhus.com,weather] http://www.visitaarhus.com/international/en-gb/menu/turist/planlaeg-book/denmarka-z/climate.htm

[www.learingsstile.dk] - www.laeringsstil.dk/omlaeringsstile.asp

[imagineschooldesign.org] - http://imagineschooldesign.org/detail.html?&tx_ttnews[swords]=sidwell&tx_ttnews[tt_news]=242&tx_ttnews[backPid]=5&cHash=d71e4980e7

[www.ebst.dk] – http://www.ebst.dk/

[http://www.iciee.byg.dtu.dk] - http://www.iciee.byg.dtu.dk/Research/Indoor%20environment%20and%20learning%20in%20schools.aspx

[IAQ and student performance] - http://innovationpartnership.org/documents/iaq_and_student_performance.pdf

[Demand-based ventilation in schools] - http://www.halton.com/halton/images.nsf/files/F9C589DD2DE7D5DDC22571B00023B5C3/$file/demand_based_ventilation_schools.pdf

[http://www.iciee.byg.dtu.dk] - http://www.iciee.byg.dtu.dk/Research/Indoor%20environment%20and%20learning%20in%20schools.aspx

[IAQ and student performance] - http://innovationpartnership.org/documents/iaq_and_student_performance.pdf

[Demand-based ventilation in schools] - http://www.halton.com/halton/images.nsf/files/F9C589DD2DE7D5DDC22571B00023B5C3/$file/demand_based_ventilation_schools.pdf

APPENDIX

APPENDIX 01 - CASE STUDIES
GREEN SCHOOLS

Just as sustainability within recent years has become a decisive parameter in the development of new areas of the city, a need for more sustainable attitude has become an even more important aspect for creating learning environments for the children.

Until now, for school authorities, improving standards and raising test scores often took priority over upgrading or maintaining facilities. But it's no longer a question of matters, people do not want their children to spend eight hour school day in buildings with poor ventilation, inadequate lighting, inferior acoustics, and inadequate heating systems.

Schools are now filling with generation of students who are being raised in more sustainable society and maintain environmental awarness, so they expect their schools to be green.

Considering that pupils spend eight hours a school day in a school building, the environment should definitely work for them, not againts them.

GREEN SCHOOLS are healthier places to learn and work, they have minimal negative impact on the environment, and lower exploitation costs besides.

Green schools use less energy, consume less water, reduce solid waste, and have lower greenhouse gas emissions than comparable conventional school.

A green school is a building constructed with focus on sustainable building materials, and energy-efficient building systems, particularly lighting and HVAC systems.

A green school can offer a much healthier indoor environment, which means fewer illnesses and lower illness-related absenteeism rates, thereby improvement in learning rates.

It can bring higher job satisfaction rates for teachers, it helps them to be more productive and perform better.

In general it motivates both teachers and children to love the environment they work in and willingly come to school every day.

A green school, however, enriches the people who use it through beautiful design, a healthy indoor environment, abundant natural daylight and outdoor views, landscaping and carefully crafted and thoughtful site plan.

"A green school is also a genuine living laboratory where students and educators expand their environmental understanding and conservation activities far beyond contributing to classroom recycling bins. The schools themselves are educational tools."
[Green school primer, 2009, p.7]

ENVIRONMENTAL EDUCATION

WORLDWIDE INITIATIVES

In 1992 United Nations (UN) held a conference in Rio de Janeiro, Brazil and the outcome of it was AGENDA 21 – an action plan for sustainable development. For the first time discussions of sustainable development paid specific attention to the educational system.
Chapter 36 focuses especially on this topic and describes how to reorient education towards sustainability, increase public awareness and what training is needed to achieve all this [agenda 21].
After Agenda 21 release many educators included sustainability into their own practices.

When pupils are asked about their future plans many paints a beautiful picture of successful career and personal life and at the same time a grim picture of the planet as a whole [K. A. Wheeler, A. P. Bijur, 2000]. It is not surprising since young people are aware of news we hear every day on media about overusing natural resources, climate change, poisoned air, water and food.

If environmental, social and economical sustainability was a part of education systems worldwide it would help greatly to create a generation that lives in peace with the nature and not overusing earth. Children can learn from a very young age to change their habits and to exercise their free will to move towards a healthy and sustainable future [www.cloudinstitute.org].

Most people do not have knowledge and skills to live a sustainable life and most of these habits are formed in schools. The school curriculum should change to adopt the needs of XXI century.

In order to do that much must be improved, starting from old and out-dated classrooms and school buildings as such and ending with learning subjects and behavior after classes and at home.

This it not only a theoretical proposal, many schools today are changing the ordinary way of education into the direction of sustainability. Case studies on pages XX are just few examples how sustainable education is successfully applied in existing schools both in Denmark and worldwide.

ENVIRONMENTAL EDUCATION ON A LOCAL LEVEL

Danish ministry of education encourages pupils, teachers and schools to include environmental issues into their study programs. After CO15 meeting, which was held in 2009, a special attention was given to put climate on the agenda. This initiative is based on 5 perspectives which should be included in educational programs. The perspectives focuses on topics like what do pupils know about earth's climate and factors that affect it or how should people change their behavior in order to avoid global warming. [http://www.eng.uvm.dk/]
A webpage www.teacherscop15.dk was established to inspire teachers to include climate issues in their everyday teaching. This webpage not only helps teachers to find ideas, but also encourages communication between pupils, teachers and schools, where they can share their projects on a local and global level. [http://www.teacherscop15.dk/]

CASES

DAY CARE CENTRE - BERNTS HAVE

Company: Henning Larsen architects
Year: (of construction) 2007 - 2009
Floor area: 1,350 m2

The new day care centre is designed with focus on energy-efficient solutions. The centre meets the Danish minimum requirements as regards energy consumption but due to its design, it contributes to reducing energy consumption. The building has a large green roof that cools down the building in the summer and contributes to insulating it in the winter.

The centre has tall glass windows that take the daylight far into the building. The walking areas of the centre form a climate zone that shields against direct sunlight and prevents overheating of the playrooms.

All the playrooms feature heat recovery ventilation while the climate zones feature natural ventilation.

The day care centre takes up part of the green spaces of Bernts Have but also gives back something new due to its green roof. [www.henninglarsen.com, boernehaven]

Ill. xx Fasade of the building

Ill. xx Courtyard of the day care centre

Ill. xx Aerial view

FREDERIKSBJERG HIGH SCHOOL

Company: Henning Larsen Architects
Year: (of constrction) 2000-2004
Floor area: 10400 m2
Frederiksberg High School in Copenhagen has an integrated solar cell system of 3 kWp - designed to fit a 140 m2 large overhead light in the entrance hall. The solar cells are fixed in the insulating glass of the overhead light to visually create the illusion of screening tiles of the same rhythm and visual size.
At night the overhead light and the solar cells are softly illuminated from within and are visible from the city's new plazas that surround the high school - providing a dramatic and poetic effect.
To further visualise the solar cell system a large display has been put up in the entrance hall, which displays the actual and overall electrical production. The data from the system is typically used in connection with the teaching of physics and natural science.
[www.heninglarsen.com, frederiksberg]

Ill. xx School interior

Ill. xx Main entrance to the school

KINGSKOLEN

Location: Slangerup, Denmark
Year of Completion: 2000
Architect: RUBOW Arkitekter
Size: 3,000 m2
Pupils: 300

The school was finished in 2001 and was a result of close collaboration between school staff, municipality and group of architects. The main concept of the school was functional clearness. The project was successful since both pupils and staff have positive responses about the building.

The building is placed around the artificial lake. Rain water is collected and led into the it. The lake is accessible from most of the corridors and provides nice views. When the weather is pleasant – pupils or staff can have lunch and sit in the garden.

Other interesting feature is the “Naturfagscentret” (the centre of natural science). “Here experiments and practical tests can be made within all subjects. The pupils can follow the function of the whole heat and ventilation facility from screens. And the pupils can read wind velocity, wind direction and outside and inside temperatures. The idea of these opportunities was that they should be a pedagogical element in the teaching.”

Natural ventilation strategy is used. The staff noticed that fewer cases of allergies and headaches were reported.

“The aesthetics of the “Kingoskole” has a positive influence on everybody at the school. Of course, we have experienced a few incidents of vandalism but generally we find that the physical surroundings of high quality makes the pupils take more care of things. Such surroundings are an obligation. Beautiful buildings have influence on the way people behave, and that is what we experience here in our everyday life,” - Per Høwbroe. [www.designshare.com]

Ill. xx The centre of natural science

Ill. xx The courtyard

SIDEWELL FRIENDS SCHOOL

Location: Washington DC, USA
Year of Completion: 2006
Architect: Kieran Timberlake
Size:3110m2 refurbishment and 3620m2 new build addition
Pupils: 340
Construction Sum:.5 million [2006]

The school was originally built in 1950's and recently needed reconstruction and expansion. Early in the design process the benefits of going "green" were discovered and applied. Three storey-wing was added to the existing school, that's how a courtyard was formed. It was developed into the landscaped wetland that treats school's waste water.
The wetland provided a rich wildlife habitat and is an exciting educational resource.

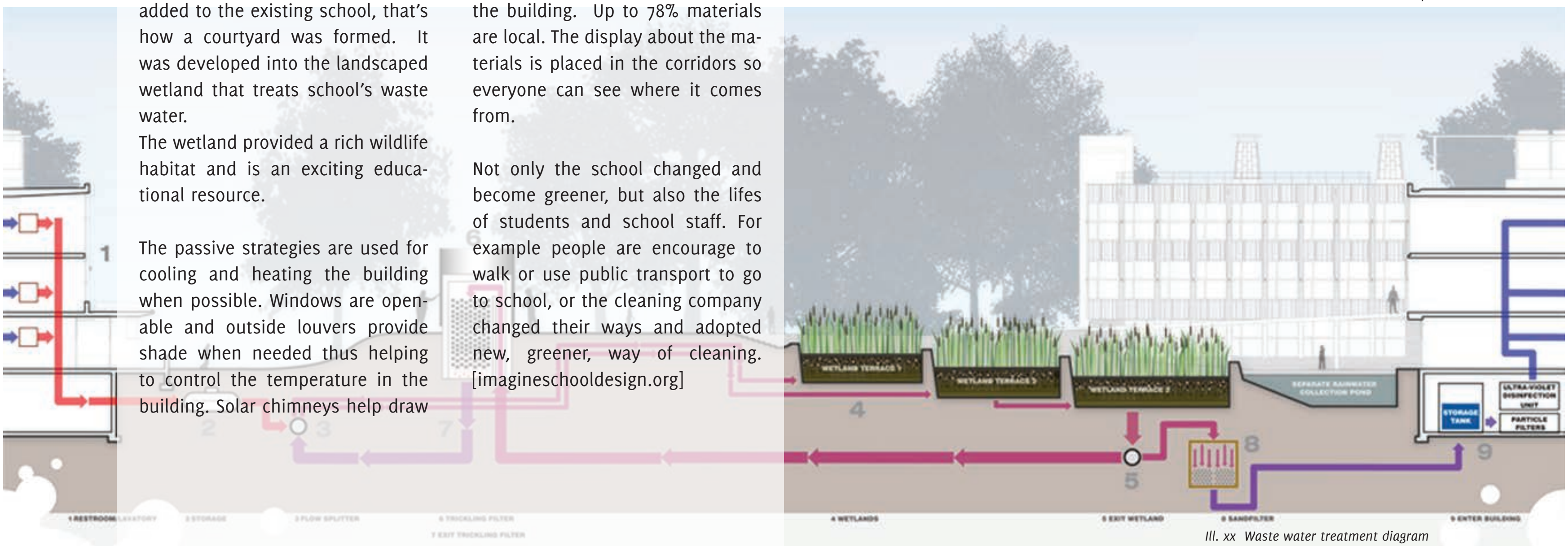
The passive strategies are used for cooling and heating the building when possible. Windows are openable and outside louvers provide shade when needed thus helping to control the temperature in the building. Solar chimneys help draw the air up, through and out to the building.

In addition to all this the pupils can use "Building Dashboard" – software to monitor "green" aspects of the building, like water and electricity consumption.

The roof is covered with grass, also with solar panels, that provide 5% of school's electricity needs.
Recycled and re-used materials were used in the construction of the building. Up to 78% materials are local. The display about the materials is placed in the corridors so everyone can see where it comes from.

Not only the school changed and become greener, but also the lifes of students and school staff. For example people are encourage to walk or use public transport to go to school, or the cleaning company changed their ways and adopted new, greener, way of cleaning. [imagineschooldesign.org]

Ill. xx The Swamp



Ill. xx Waste water treatment diagram

APPENDIX 02 - AIR CHANGES CALCULATIONS

ROOM CHARACTERISTICS - CLASSROOM A

floor area: 80 m^2
room height: 3,5 m
room volume: 280 m^3
occupancy: 28 pupils, 2 teachers / 80 m^2 = 0,375
activity, person: 1,2 met

AIR QUALITY category A (CR 1752)

indoor air quality: 1,0 dp (table A.5, CR 1752)
outdoor air quality: 0,1 dp (table A.9, CR 1752)
perceived level of CO_2 outdoor: 350 ppm (table A.9, CR 1752)
perceived level of CO_2 above outdoors: 460 ppm (fig. A.8, CR 1752)
limit CO_2 indoor: 810 ppm

SENSORY POLLUTION LOAD

pollution, person, pupil: 1,3 olf (table A.6, CR 1752)
pollution, person: 1 olf (table A.6, CR 1752)

POLLUTION BASED ON CO_2

CO_2 given off, person, pupil: 17 x M x 06 = 12,2 l/h
CO_2 given off, person: 17 x M x 06 = 20,4 l/h

SENSORY POLLUTION LOAD

occupants (29pupils / 80m2): 0,375 x 1,3 = 0,487 olf/m^2
buildings: 0,1 olf/m^2
in total: 0,587 olf/m^2

REQUIRED VENTILATION RATE FOR COMFORT

(equation A.2, table A.5, CR 1752)
category A: Q_C = 10 x G_C / ($C_{C,i}$ - $C_{C,o}$) x 1/1 = 10 x 0,587 / (1,0-0,1) x 1/1 = 6,53 l/s/m^2

air change rate: 6,53 l/s/m^2 x 3,6 x 80 m^2 = ***6,71*** h^{-1}

BASED ON CO_2 IGNORING THE BUILDING AS POLLUTION SOURCE

occupants when activity - 1,2 met: (28 x 12,2) + (2 x 20,4) = 382,4 l/h
CO_2 above outdoors: 460 ppm

REQUIRED VENTILATION RATE

(equation A.3, table A.6, fig. A.8, CR 1752)
category A: Q_h = G_h / ($C_{h,i}$ - $C_{h,o}$) x 1/1 = (12,2 x 28 + 20,4 x 2) / 3600 x 460 ppm x 10^{-6} = 230,9 x 3,6 = 831,3 m^3/h

air change rate: 831,3 m^3/h / 280 m^3 = ***2,98*** h^{-1}

THERMAL COMFORT

Internal heat load
28 x 54W x 8h = 13536 Wh
2 x 90W x 8h = 1440 Wh
4W/m^2 x 80 m^2 x 8h = 2560 Wh

Solar heat load
west: 0,5 x 0,9 x 0,9 x 0,9 x 0,9 x 12 m^2 x 3132 Wh/m^2 = 12329 Wh

in total: 28425 Wh

Temperature difference
indoor air temperature: 24,5 °C
indoor air temperature: 21 °C
difference: 3,5 °C

Specific ventilation loss
0,34 x 280 m^3 = 95,2 W/°C

Specific transmission loss
walls
23 m^2 x 0,3 = 6,9 W/°C
windows
12 m^2 x 1,4 = 16,8 W/°C
in total: 23,7 W/°C

AIR CHANGE RATE

n = ((2560 + 12329) / 54 * (24,5 - 21) - 23,7) / 95,2 = ***3,31*** h^{-1}

APPENDIX 03 - VE
SHADING DEVICES

0,5m overhang

Classrooms		Shared areas	
>26	>27	>26	>27
South - 143	South - 62	South - 147	South - 85
East - 158	East - 73	North - 51	North - 15
West - 58	West - 24		
North - 60	North - 25		

1m overhang

Classrooms		Shared areas	
>26	>27	>26	>27
South - 56	South - 30	South - 115	South - 64
East - 87	East - 19	North - 28	North - 7
West - 39	West - 14		
North - 46	North - 16		

Horizontal louvers 100mm with 200mm gaps

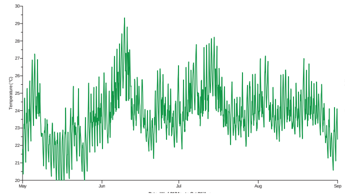
Classrooms		Shared areas	
>26	>27	>26	>27
South - 39	South - 11	South - 97	South - 53
East - 51	East - 11	North - 23	North - 5
West - 33	West - 11		
North - 38	North - 13		

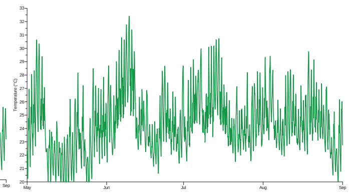
Vertical louvers 100mm

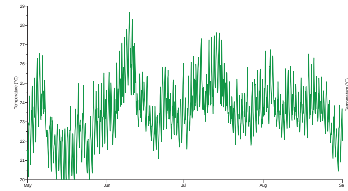
Classrooms		Shared areas	
>26	>27	>26	>27
South - 152	South - 67	South - 128	South - 54
East - 190	East - 97	North - 54	North - 18
West - 55	West - 23		
North - 47	North - 17		

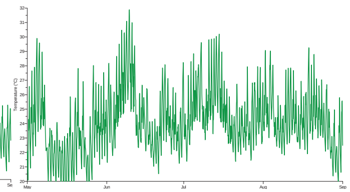
Curtain net

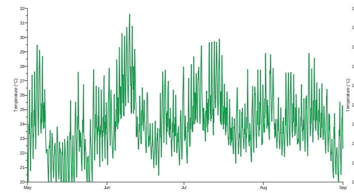
Classrooms		Shared areas	
>26	>27	>26	>27
South - 84	South - 45	South - 64	South - 31
East - 92	East - 26	North - 14	North - 2
West - 23	West - 9		
North - 20	North - 5		

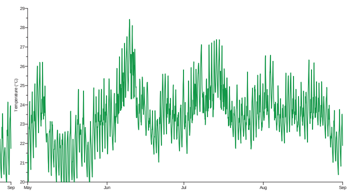

North shared area

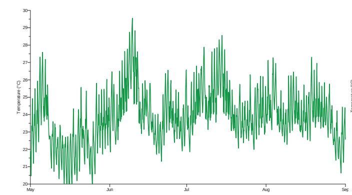

South shared area

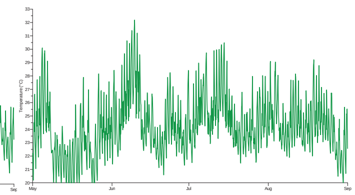

North shared area

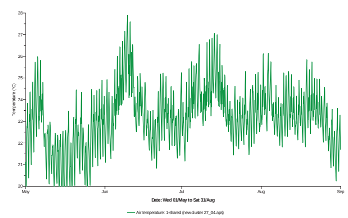

South shared area

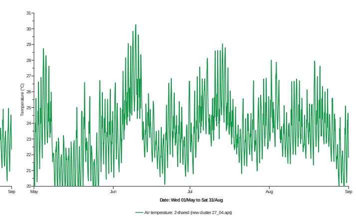

North shared area

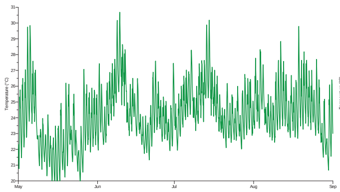

South shared area


North shared area

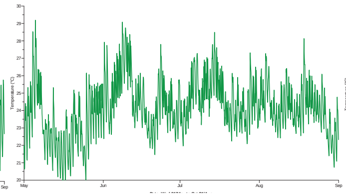

South shared area


North shared area

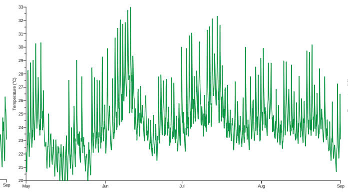

South shared area



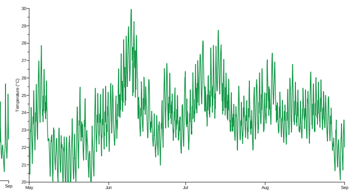
South classrooms



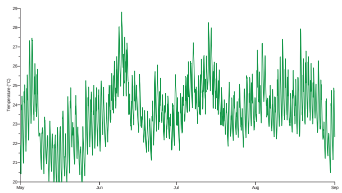
East classrooms



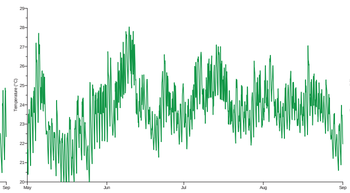
West classrooms



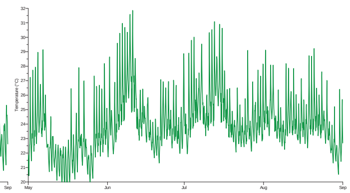
North classrooms



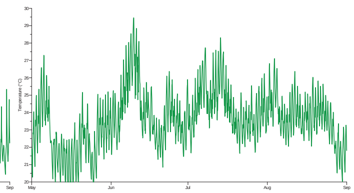
South classrooms



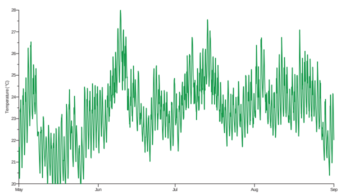
East classrooms



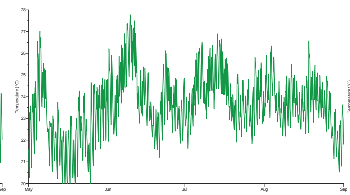
West classrooms



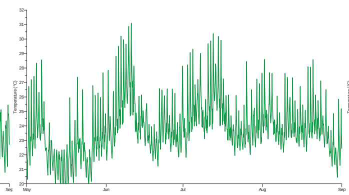
North classrooms



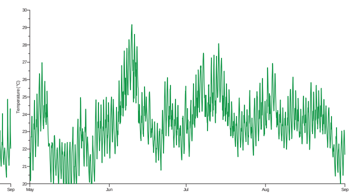
South classrooms



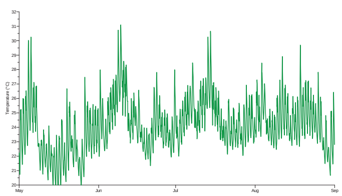
East classrooms



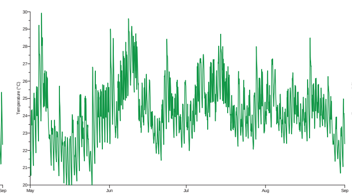
West classrooms



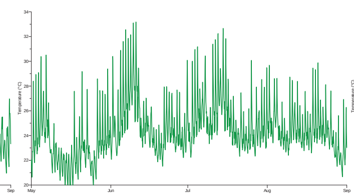
North classrooms



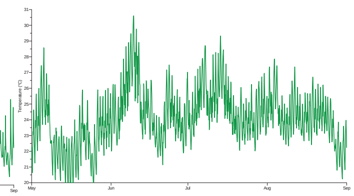
South classrooms



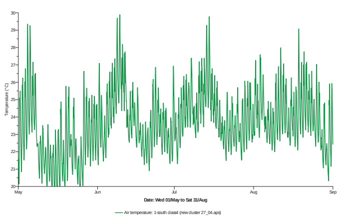
East classrooms



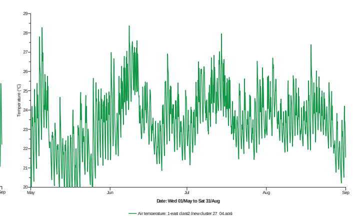
West classrooms



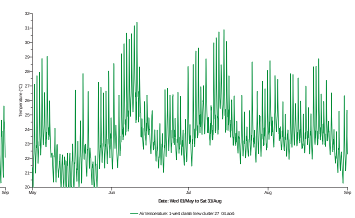
North classrooms



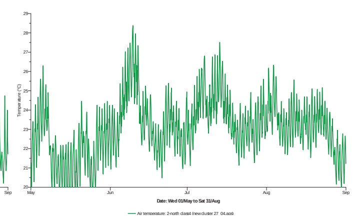
South classrooms



East classrooms

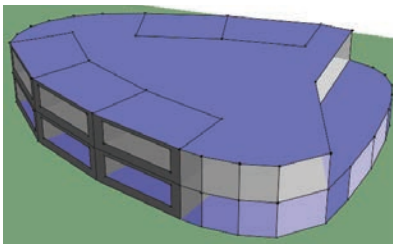


West classrooms

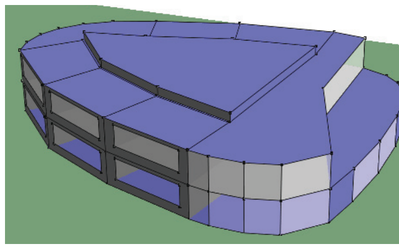


North classrooms

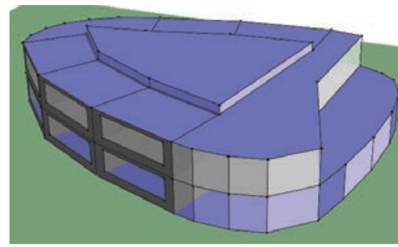
SKYLIGHTS



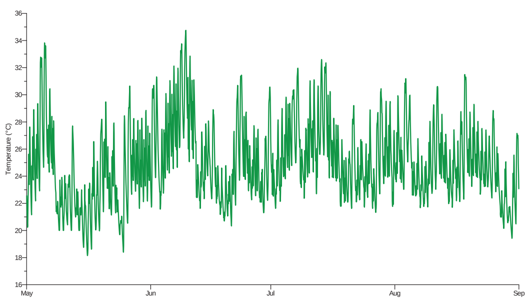
Overheating
first floor
>26 - 55
>27 - 19
ground floor
>26 - 16
>27 - 4

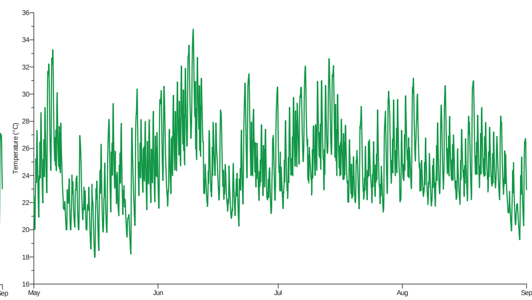


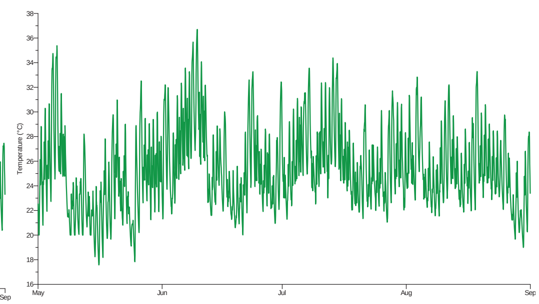
Overheating
first floor
>26 - 45
>27 - 13
ground floor
>26 - 25
>27 - 7

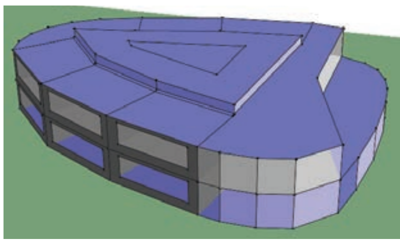


Overheating
first floor
>26 - 79
>27 - 35
ground floor
>26 - 29
>27 - 8

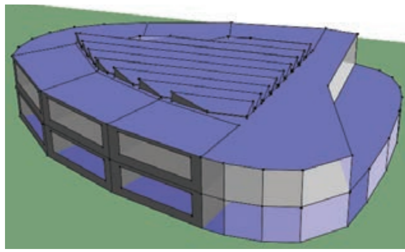




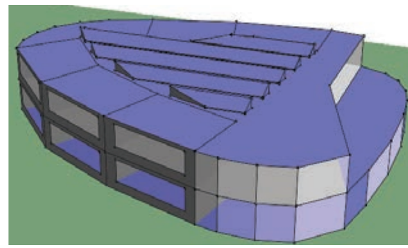




Overheating
first floor
>26 - 107
>27 - 43
ground floor
>26 - 27
>27 - 7



Overheating
first floor
>26 - 87
>27 - 31
ground floor
>26 - 26
>27 - 7



Overheating
first floor
>26 - 64
>27 - 21
ground floor
>26 - 16
>27 - 3