The windows of Herman Hertzberger’s Montessori school in Delft

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Introduction

Schools are intermediate spaces: they are neither public nor private. How the architect discerns the inside from the outside is important, as it defines the circumstances in which children enter the public space (Van Den Driessche, 2007, p.94). Architecture sets up boundaries to define and delimit different spaces. Windows' design, tectonics, and placement are crucial as they connect those separated spaces. They are a meeting point for a lot of information. Through their form and construction, windows inform us about the socio-cultural context and the production system networks in which they were created (Tsukamoto, 2023, p. 28).

Herman Hertzberger's Montessori school in Delft will be used as a case study. Schools are the most important type within Hertzberger's oeuvre (McCarter, 2015, p.141). The Delft Montessori school was Hertzberger's first school building, he started designing it only 2 years after his graduation. At the start of the 1960s, the administrative board of the Delft Montessori school commissioned him to create a school that better fits the Montessori ideas, accommodating different types of independent or communal activities in one classroom (Hertzberger, 2008, p. 31). Hertzberger's response was to develop a design based on a snail shell: the innermost part of the classroom is for autonomous tasks, whilst the outer part is for joint activities (Hertzberger, 2008, p. 32).

Hertzberger uses windows to articulate these different types of spaces. Skylights are used to define the entrance to the classrooms. The area adjacent to the entrance, of lower height and lowered by two steps, is intended for manual work. Windows connect it visually to the central hall. The area near the windows, higher and brighter, is dedicated to activities that require greater concentration, such as mathematics (Baglione, 2006, p.56).

This research aims to shed light on the design practices of Herman Hertzberger from the perspective of production system networks and cultural practices of the Montessori educational philosophy. By studying a specific example and element: the windows of the Montessori school in Delft by Herman Hertzberger, the following research question will be answered: How do the windows of Herman Hertzberger's Montessori school in Delft reflect the cultural practices of the Montessori educational philosophy and the production system networks of the 1960s? Some sub-questions are: (1) Where do Hertzberger's windows stand between industrialisation and craft; (2) How do the windows respond to the regulations and norms for school windows of the 1960s and (3) How do the windows serve as spatial tools to implement the Montessori philosophy.

Much has been written about Hertzberger's œuvre and schools, providing a chronological overview of his work or focusing on his design philosophy. This paper is mainly inspired by the work of Tsukamoto (2023) and the Chair of Architectural Behaviorology at ETH Zurich (2023). By meticulously studying different window designs, they try to demonstrate how climatic and cultural conditions and technological developments shape the architecture of windows. Similarly, by zooming in on a specific part of a building, the window, this paper will try to unravel new facets of Hertzberger's design for the Montessori school in Delft and the historical context in which he was working.

The methodology adopted consists of the following steps. For background information about the historical context, regulations in the 1960s, the production system network and general information about Hertzberger's design, secondary sources were consulted. Secondly, to find out more about the three specific windows he designed (skylight above the cloakroom, window looking into the hall and window facing the outdoors), primary sources from the archive of the Nieuw Instituut were consulted. To summarise the data gathered, technical drawings of the windows were

made. Finally, the information collected from secondary sources and the technical drawings was compared.

This paper is divided into four chapters and a conclusion. The first chapter describes the historical context in which the school was built and gives an overview of Hertzberger's design ideas for the school. The second chapter identifies existing regulations and norms for school windows and production system network of windows during the 1960s. The third chapter covers the three specific windows, their material composition and measurements. The fourth chapter confronts the findings of chapter three with the broader context, documented and explained in chapters one and two, by confronting Hertzberger's windows with the broader context of the industrial and cultural practices of the Montessori educational philosophy. Finally, the conclusion summarises the main points and findings of the paper.

1 Schools in the Netherlands in the 1960s and Herman Hertzberger's Montessori school

1.1 Historical context of the Montessori school in the Netherlands

In 1801, the Government of the Netherlands adopted strict rules and regulations for primary schools (Steijns & Koutmanis, 2004, p. 17). The rules meant education was organised, standardised, and legally mandated (Steijns & Koutmanis, 2004, p. 12). It cemented the classical education system: communal, using a chalkboard. Through these regulations, schools became recognisable buildings with a specific spatial arrangement, tailor-made for certain activities (Steijns & Koutmanis, 2004, p. 20).

Due to the inexperience of architects with the classical educational system, a model school was developed in 1811. It became the basis for the typology of the corridor school, which stayed the standard prototype till the end of the 20th century (Boersma et al., 1996, p. 17). Its main characteristics were: classrooms aligned in a row and connected by a long corridor. Internally, the classrooms are organised as units, with all pupils facing the teacher (Steijns & Koutmanis, 2004, p. 21).

Few other typologies were developed as a result of the strictness of the regulations and limited financial resources (Steijns & Koutmanis, 2004, p. 21). The regulations focused mostly on technical aspects: hygiene, light and air. Detailed rules about fresh air, the amount of natural light, sight and hearing distances, and the arrangement and nature of the furniture allowed for very limited design freedom for the architect (Boersma et al., 1996, p. 90).

From the start of the 20th century onwards, the traditional education system and the typology of the corridor school were increasingly criticised for their passive classroom-based learning. Additionally, from 1920, new legislation for primary schools (Wet op het Lager Onderwijs) resulted in equal access to subsidies for both public and private education (Steijns & Koutmanis, 2004, p. 24). Alternative methods of education thus gained popularity, in particular Steiner-, Dalton-, Jenaplan- and Montessori schools. In 1914, the first Dutch Montessori school was opened in Den Haag. The influential 1949 school issue of the architecture magazine Forum praised the English schools as an example of not strictly classroom-based education. The reform schools. exemplified a more individualised education with a more loose class affiliation and differentiation of groups using playrooms, handicraft rooms and a school hall (Leupen, 1945).

After the Second World War, this critique eventually resulted in educational reforms. New working methods were developed that broke the rigid relationships in the classroom and encouraged students to work more independently (Boersma et al., 1996, p. 10). Despite that, the larger part of the educational system didn't change much, and most schools remained passive sit-and-listen schools. The exception were the reform schools, which experimented with innovative solutions for a tighter connection between pedagogy and the world of the child (Boersma et al., 1996, p. 12).

In comparison to previous decades, in the 1950s there was more room for experimentation (Steijns & Koutmanis, 2004, p. 27). Increased demand for specialised classrooms and rooms for group activities required new solutions. The 1953 report of a committee on school construction *(De nieuwe school voor het lager onderwijs: Rapport van de studiecommisie voor scholenbouw)* depicted the school as a community *(Secretariaat van de Studiecommissie, 1953)*. This vision led to the development of new typologies such as hall- and pavilion schools (Steijns &

Koutmanis, 2004, p. 27). In this type of school, the hall functions as a connection between the different classrooms and a communal space for socialising.

An example of an influential architectural innovation is the school in Nagele (1954-1957) by Aldo Van Eyck. This building features six uniformly sized classrooms with an irregular shape, arranged around a multifunctional corridor (Steijns & Koutmanis, 2004, p. 9). Although the hall was not always considered an educational space, and varied in size, this school type nevertheless produced remarkable architecture as it was in line with the ideology of community prevalent in reform schools (Boersma, 1996, p.179).

The Delft Montessori school of Herman Hertzberger is an example of a hall school where the architectural and educational concepts fit together almost seamlessly (Boersma, 1996, p.195).

1.2 The Montessori educational philosophy

Montessori educational method

Maria Montessori recognised, whilst working with children with intellectual disabilities, the need for suitable teaching methods rather than medical treatment. Her teaching approach was developed through scientific observation and experimentation in the first Montessori school, "Casa dei Bambini", established in 1907 in Rome (Okuo, 2014, p.4). One observation she made is that children go through periods where they are more or less receptive to learning and therefore benefit from self-directed activities (Marshall, 2017, p.1). Her educational model highlights the dynamic interaction between child, teacher, and the environment. The teacher's role is to guide the child through a "prepared environment", a classroom with learning materials that encourage exploration and independent learning (Marshall, 2017, p.2).

In her book *Il metodo della Pedagogia Scientifica* (1909), Maria Montessori describes the features of the 'Children's House', an ideal learning environment for children. This space should function as a home with various areas for different activities: a dining room, a gymnasium, a dressing room, a garden and a room for intellectual work. The furniture is lightweight, making it easy for students to move around and clean. Learning materials are stored within the children's reach through accessible storage units in the classroom. The children's living room has a cosy and inviting atmosphere with musical instruments and a shared space for reading stories. The dining area features tables and low cupboards, so children can easily access and put away their crockery. Nearby, the dressing room includes individual cupboards for each child, along with a table fitted with small water basins (Surum & Omondi Kauka, 2019, p.221).

Architecture of Montessori schools

Maria Montessori has not provided clear guidance on the architectural requirements for a Montessori school. But over the years, as more schools have been built, some typological similarities have been pointed out. Steve Lawrence and Benjamin Stæhli's book *Montessori Architecture: A Design Instrument for Schools* (2023) attempts to explain the phenomenon of Montessori Architecture by showing examples from around the world. In the chapter 'Patterns', they distil 28 patterns, identified from their worldwide survey of Children's Houses (Lawrence & Stæhli, 2023).

Some patterns focus on the function and spatial articulation of the classroom. For example, pattern 01: "A hierarchy of interconnected spaces, adapted to children's activities" details that children require space to explore freely and feel secure. A hierarchy of interconnected spaces of varying dimensions and arrangements facilitates this orientation. The school should resemble a landscape, and therefore it is important to articulate the space by raising or lowering sections of the floor and ceiling (pattern 2). Similarly, as privacy is important for concentration, it is suggested to divide the space into smaller, distinguishable components (pattern 7). The articulation of the walls is equally significant. Both patterns 11 and 12 explain the need for sufficient shelving and storage space to display the learning materials and promote independent work. Windows and daylight are also important components. The interaction between the classroom and garden is facilitated by window seats and -sills. These create differentiation and allow for a specific kind of activity (pattern 15). Different spaces and activities require specific lighting conditions (pattern 17). For example, light from above, with a skylight, can model the outdoors (pattern 16).

Early examples of Montessori school architecture in the Netherlands

Some influential early examples of Montessori school architecture that inspired Hertzberger are the Montessori school in Corellistraat, Amsterdam (1927) by A.R. Hulshoff (Fig.1) and the Montessori school in Valkeveen by Brinkman & Van der Vlugt (1926) (Fig.2).

In comparison to other schools built in that period, the specificity of the Montessori school in Corellistraat consists of two extra spaces: a tiled kitchen space with a large low-lying sink and a side area much like a sitting room. This sitting space is separated from the main room by a passage lined on both sides by cupboards with glass doors. There are fixed benches with cushions to read or rest, to offer a calm space to concentrate on your work (Hertzberger, 2008, p.26). The school in Valkeveen, designed by the architects of the Van Nele Factory, is a more traditional construction. It consists of a singular classroom with 4 identical lower rooms at the corners with bay windows. The configuration of the classroom is an early example of an "articulated" teaching space (Hertzberger, 2008, p.30). With the term "articulated classroom", Hertzberger refers to a spatially diverse environment that is broken up into distinct zones with alcoves, niches, and semi-enclosed areas (Hertzberger, 2008, p.24).

Figure 1-
Floorplan of Montessori school classroom, Corellistraat, A.R. Hulshoff - 1927

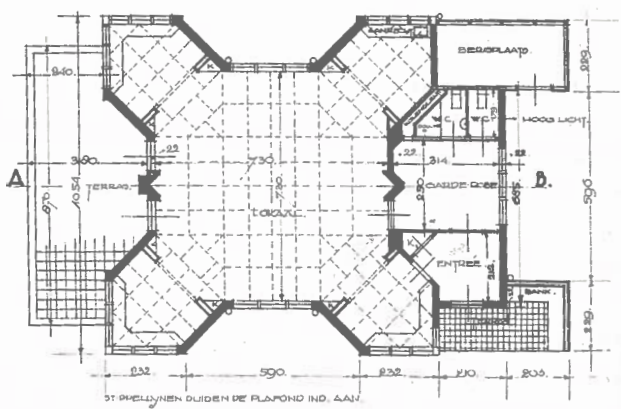
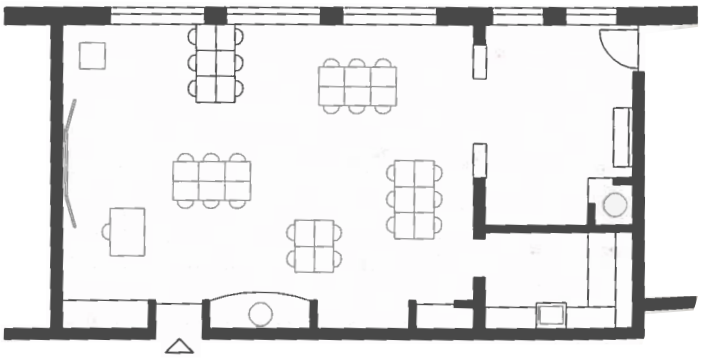
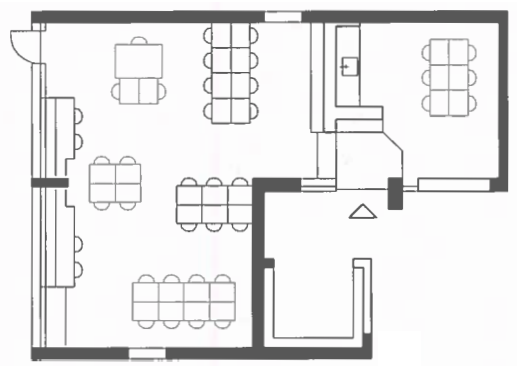


Figure 2-
Floorplan of Montessori school, Valkeveen, Brinkman & Van der Vlugt - 1926



Hertzberger's Montessori school in Delft fits into the mold described above of a typical Montessori school. However, Hertzeberg's design is an improvement on the earlier examples seen in Amsterdam and Valkeveen. Similarly to A.R. Hulshoff's design, the classroom has two extra spaces (Fig.3): a sitting area and a tiled kitchen area; however, as the reading nooks in Brinkman & Van der Vlugt's classroom, they are part of the same, articulated classroom.

Figure 3-
Floorplan of Montessori school, Delft, Herman Hertzberger - 1966



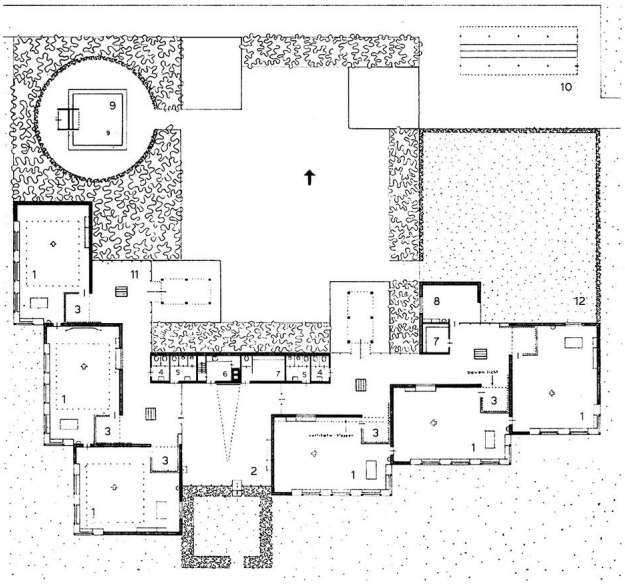
1.3 Hertzberger's design for the Montessori school in Delft

At the start of the 1960s, the administrative board of the Delft Montessori school commissioned Hertzberger to design a primary school and kindergarten that better fit the Montessori ideas (Hertzberger, 2008, p. 31). Since 1966, the building has undergone four different series of extensions, the last one was realised in 1981 (Baglione, 2006, p.58). The scope of this paper focuses on the windows of a singular classroom, of the typology specific to the first construction as well as the second (1966) and third extension (1968).

Hertzberger explains in an interview for Casabella that his school design was heavily inspired by the school in Nagele by Aldo Van Eyck (Fig.4) (Baglione, 2006, p.61). Some of the innovative solutions of the school in Nagele, which are also visible in Delft, are: the articulation of the hall space through the placement of the classrooms, the use of skylights above cloakrooms at classroom entrances, and the inclusion of windows on walls separating classrooms from the hall.

Hertzberger focused his research at the Delft School on the design of classrooms, specifically within the framework of Montessori principles (Baglione, 2006, p.61). He drew a lot from his own experiences, having attended Montessori schools, and was informed by his wife, a Montessori teacher. At its core, he intended to create tailored solutions to enhance the intrinsic curiosity and independent learning capabilities of children. His design allows for various simultaneous activities, whether individual or in small groups, while enabling the teacher to oversee the entire class (Baglione, 2006, p.56).

Figure 4- Floorplan of school in Nagele, Van Eyck - 1956



Layout of the school

The position of the building dissolves the rigid divide between the street and the school. The entrance is oriented towards the neighbourhood, located within two busy ring roads (Fig.5) (Van Den Driessche, 2007, p.78). The school is structured around a central hall with classrooms designed as independent units connected to the interior hall and the garden (Fig.6). Hertzberger often refers to the school, the hall and the classroom using the analogy of a house and a street (Baglione, 2006, p.61). The light is an important factor in differentiating these components. As Hertzberger states: “If the school is supposed to be a city, it’s very important where the light comes from, from the side or from above. In the streets, the light comes from above’’ (Dyer, 2016).

Hertzberger’s design emphasises articulated communal spaces, distinguishing them from undifferentiated spaces. For example, the shared space is punctuated by different elements: a brick podium that transforms into a stage with the addition of wooden elements (Fig.7) and a pit with wooden stools that children can rearrange (Fig.8) (Hertzberger & TU Delft, 1984, p.67). These elements are the means to make different activities possible (Van Den Driessche, 2007, p.85). Similarly, the use of humble materials such as perforated concrete bricks makes for a simplicity and purity of form, which encourages imaginative use and expression (Baglione, 2006, p.58).

Figure 5- Situation plan Montessori school, Delft, Herman Hertzberger - 1981

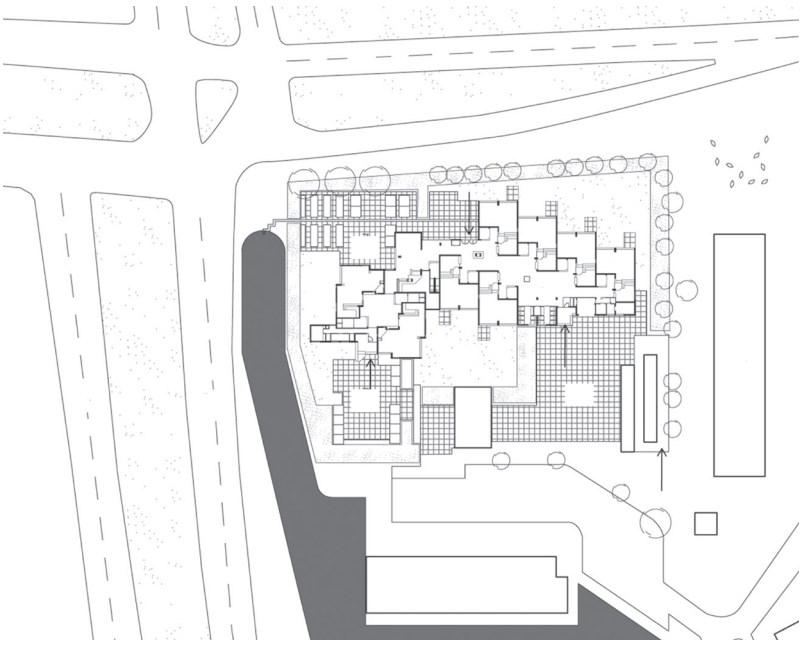


Figure 6- Floorplan
Montessori school, Delft,
Herman Hertzberger - 1966

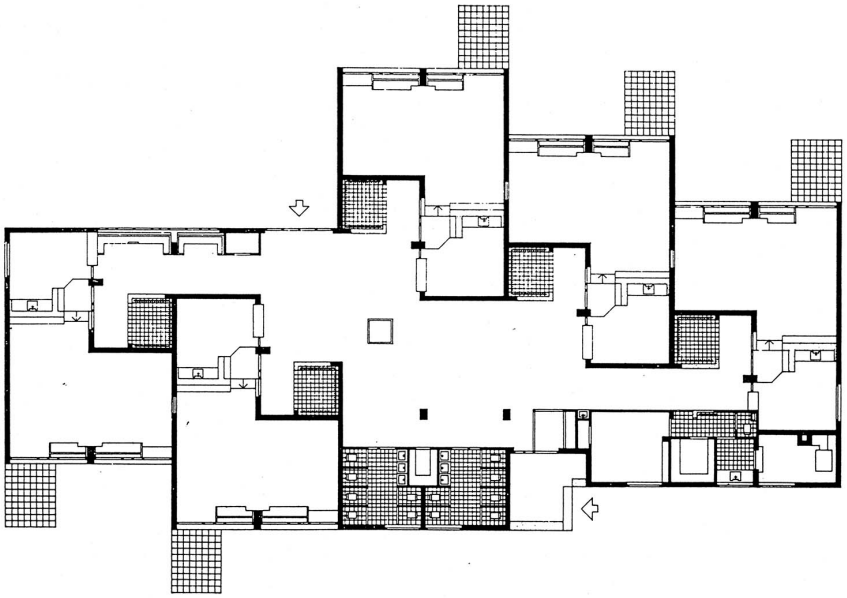


Figure 7- Brick podium,
Montessori school, Delft,
Herman Hertzberger - 1966

Figure 8- Sitting pit,
Montessori school, Delft,
Herman Hertzberger - 1966

Layout of the classroom

The class is meant to mimic the interior of a home, featuring varied, irregular spaces and quiet corners that allow children to work and reflect at their own pace. The classroom is described as a continuous, articulated space, a series of zones that progress from secluded to increasingly communal, the classroom seamlessly flowing into the shared central space (Fig.9). Ensuring that areas meant for quieter intellectual work are spatially separated from those meant for more energetic activities, such as painting and clay modelling (Hertzberger, 2008, p. 31).

Figure 9- Floorplan classroom, Delft, Herman Hertzberger - 1966

This in practice leads to an L-shaped plan with a large space (40 m²), an antechamber (12 m²) and a cloakroom in the hallway (8 m²) (Van Den Driessche, 2007, p.89). The outermost space, adjacent to the cloakroom, is illuminated by a skylight. It is a workspace where children can engage in individual or small group activities while remaining close to their classroom (Fig.10). An alcove formed by low walls serves as a cloakroom (Van Den Driessche, 2007, p.89). Inside the classroom, the area adjacent to the entrance, of lower height and lowered by two steps, is intended for craftwork (Fig.11). Windows connect it visually to the central hall (Fig.12). The lowered floor shields the creative area to avoid distraction. The area with windows along its entire width, higher and brighter, is dedicated to activities that require greater concentration, such as mathematics (Fig.13, 14) (Baglione, 2006, p.56).

The windows play a pivotal role in both defining the different workspaces and creating distinct atmospheres in the classroom.

Figure 10- Workspace outside the class room, Montessori school, Delft, Herman Hertzberger - 1966

Figure 11- Manual work area, Montessori school, Delft, Herman Hertzberger - 1966

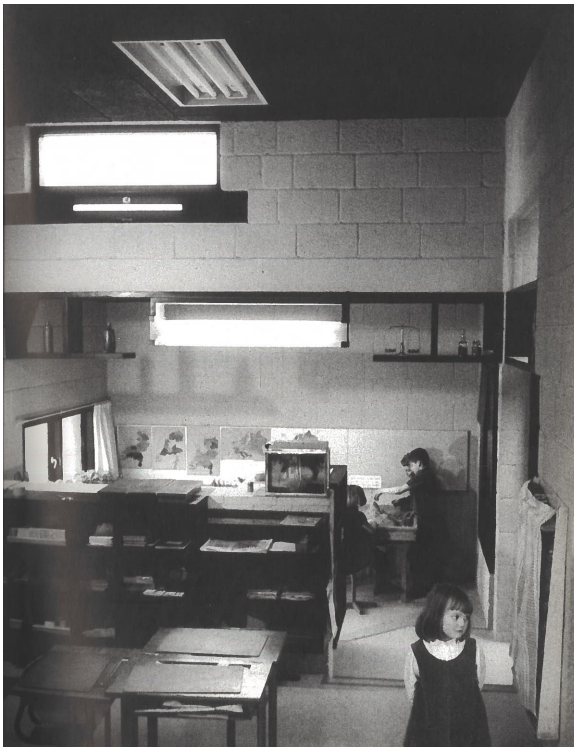
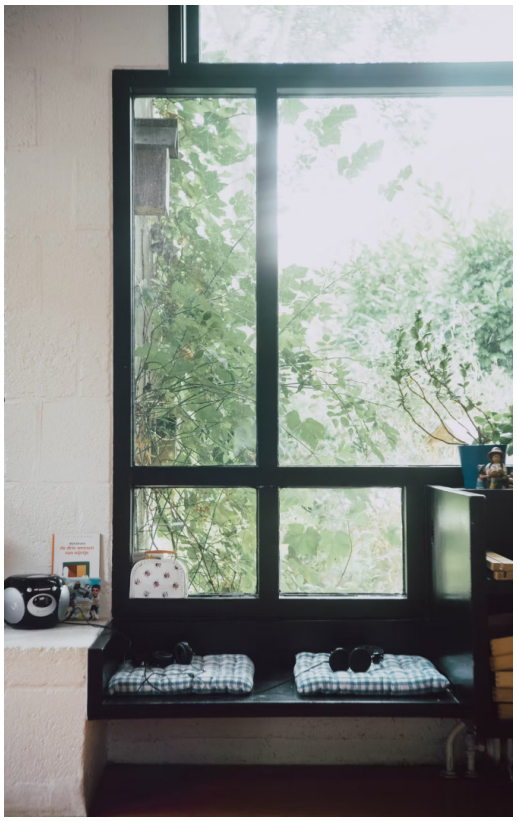


Figure 12- Showcases above the entrace to the classroom, Montessori school, Delft, Herman Hertzberger - 1966

Figure 13- Wooden table built into windowsill, Montessori school, Delft - 2018

Figure 14- Built in seat, Montessori school, Delft - 2018



2.1 Regulations and norms: What were the regulations and norms for school windows in the 1960s?

In the 1950s and 1960s, architects faced challenges due to outdated building regulations. Primarily, the 1924 Bouwbesluit, which remained in force until the late 1950s. It restricted school layouts, as it was written with the typology of corridor schools in mind (Boersma, 1996, p. 182). Among other things, it stipulated that daylight had to come from the left, to prevent the hand's shadow from falling on the notebook (Bouwbesluit 1924, art. 10, lid 1). This not only defined the school's orientation as a whole but also the strict arrangement of furniture in the classroom (Boersma, 1996, p.94). In 1959, a revised Bouwbesluit was introduced that was more in line with modern challenges, such as standardisation, rationalisation and lower costs. It encouraged smaller school buildings with larger classrooms (maximum 56 m² per classroom) and movable furniture. It established a maximum price per classroom (Loeff et al., 2005, p. 21), and ancillary rooms and auditoriums were restricted (Boersma, 1996, p.182).

The Bouwbesluit of 1924 is widely described and cited in literature; however, the information available on the later regulations is very scarce. Only a journal from Bouwcentrum (1953) mentions a Bouwbesluit of 1936. The Bouwbesluit kleuteronderwijs of 1957 is partly cited in the book *Kleuterscholenbouw : de administratieve procedure : nieuwe scholen in beeld* (1958). Both Loeff et al. (2005) and Boersma (1996) mention a new Bouwbesluit of 1959. Under the name of Staatsblad (the publication journal for the new laws of the Netherlands), the Bouwbesluit of 1959 was eventually found in Het Rijksarchief. However, it could not be consulted in time. As regulations usually change incrementally, the Bouwbesluit of 1924 will be described and used for comparison purposes, even though the design of the Montessori school had to conform to the more modern regulations of 1959. The Bouwbesluit kleuteronderwijs of 1957 is also relevant, as the Montessori school in Delft is both a primary school and a kindergarten.

According to Rothuizen (1924), in *Scholenbouw,* some of the rules of the 1924 Bouwbesluit are conflicting. The decree states that the windows must be installed so the sun's rays enter the classroom for a few hours a day, but excessive daylight must be tempered (Bouwbesluit 1924, art. 10, par. 2-3). Other rules are more straightforward. Natural light must come from the left, and no windows can be placed on the opposite walls of the classroom (Bouwbesluit 1924, art. 10, par. 1). Glass must cover at least 1/6 of the surface of the facade and, if interrupted by tall buildings or trees, 1/5 of the floor area (Bouwbesluit 1924, art. 10, par. 2). The parapet of the windows was set at 1 m above the floor (Bouwbesluit 1924, art. 10, par. 5). Article 10 of the Bouwbesluit 1924 stipulated that at least half of the total surface area of the lower windows in each classroom should be openable (Bouwbesluit 1924, art. 10, par. 7). The need for good ventilation was further reinforced by the requirements for the upper windows, which had to be constructed to allow for natural ventilation during courses (Bouwbesluit 1924, art. 10, par. 6). The Bouwbesluit also laid down strict rules for the placement of doors. Article 11, paragraph 3 stipulated that doors had to open outwards and not cause any obstruction in the corridor. Furthermore, the upper part of the door must be fitted

with a glass panel, at 1.40 m from the floor, for the teachers to be able to look through.

The Bouwbesluit kleuteronderwijs of 1957 marked a significant step forward, as before, there were only unofficial guidelines for the construction of kindergartens. The decree closely followed the Bouwbesluit of 1924 for Primary Education (Kleuterscholenbouw, 1958, p. 94). Article 10 concerns the admission of light into the rooms. The light must enter in one of the following ways: a) directly through both side walls, b) directly through one side wall and the rear wall, or c) directly through one side wall and indirectly through the other side wall. For the latter option, it is stated that indirect admission of light via a hall space is not sufficient. The parapet must be at least 0.40 m above the floor for all windows in the room, and for the main windows in the outer wall, 0.60 m above the floor. In addition, it is stipulated that at least half of the windows, both upper and lower, in the room must be openable (Kleuterscholenbouw, 1958, p. 94).

The 1924 Bouwbesluit severely restricted innovation in school layouts. The more recent regulations, less restrictive in terms of daylight concerns, permitted more experimental typologies.

2.2 The production system networks, a balance between industrialisation and craft: How were window frames made in the 1960s?

In the 20th century, several consecutive innovations in the glass manufacturing process led to the production of larger quantities of glass, eliminating earlier size restrictions. The lower price, accessibility and improved transparency influenced architectural designs (Wolf et al., 2024, p.19). New methods were developed to simplify the production process and reduce costs. Both Émile Fourcault, in 1902 and Irving W. Colburn and Edgar Washburn, in 1904, patented the production techniques to make a continuous sheet of glass drawn from a melting tank. The machine-drawn sheet was the dominant production method from the 1920s until the 1960s (Wolf et al., 2024, p.19). It was replaced by the float-glass process, a revolutionary innovation, as it allowed molten glass to be continuously fed from one side onto a bath of liquid tin (Pender & Godfraind, 2011, p.26). The result was a high-quality, flawless, transparent, and smooth sheet of glass up to 2.5 meters wide. The low production costs and flexibility in thickness and dimensions revolutionised the glass industry and became widely used for windows by the start of the 1960s (Wolf et al., 2024, p.24). Since the invention of float glass, most innovations have centred around the development of glass-treatment techniques, toughened-, tempered-, and laminated safety glass (Pender & Godfraind, 2011, p.26).

Before the availability of sheet glass, larger window frames were often divided with other window frames to make several lights, with a few casements, and openable windows, attached to the main frame by one or multiple hinges (Pender & Godfraind, 201, p.106). With the production of continuously drawn sheet glass, large squares of glass were available. Therefore, by the 1920s, windows often incorporated a large light, or dead light (Barry, 1958, p.20). Since the 21st century, woodworking machinery has been increasingly used to prepare, cut and assemble windows and

doors. Mostly, standard sizes for windows and doors are machine-made, while non-standard sizes are still hand-made (Barry, 1958, p.21).

A difference between machine-made and handmade is the types of joints. The casements and frames of mass-produced windows have a combed joint and interlocking tongues cut on the ends of members which are put together, glued and pinned (Fig.15) (Barry, 1958, p.21). Handmade windows are made with a mortice and tenon joint, by a joiner, aided sometimes by hand-operated machines. The joint uses a protruding tenon, cut on the end of one section, which fits into a matching mortice on the other, the joint being made secure with glue and wedges (Fig. 16) (Barry, 1958, p.20). Another way to differentiate between the two is the types of instructions given by the architect or contractor. With machine-made windows, it is practice to specify the precise finished size of each member, as this is the dimension the operator needs to set up the machine. It is up to the operator to select the size of timber used (Barry, 1958, p.21). For handmade, it is usual to specify the sizes of the rough-sawn timber needed for the members of the windows, doors and frames. This enables the joiner to shape and smooth the wood without worrying about an exact final size. The required size for the window will be achieved during the assembly (Barry, 1958, p.21).

Figure 15- Combed joint, the construction of buildings, Barry - 1958

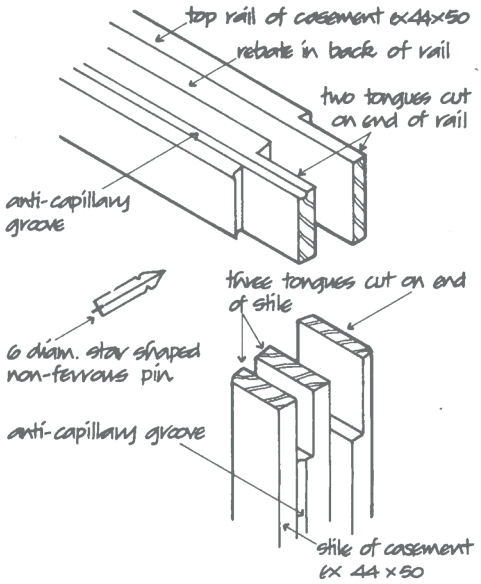
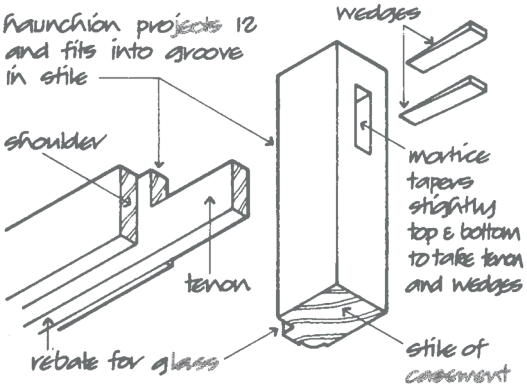


Figure 16- Mortice and tenon joint, the construction of buildings, Barry - 1958

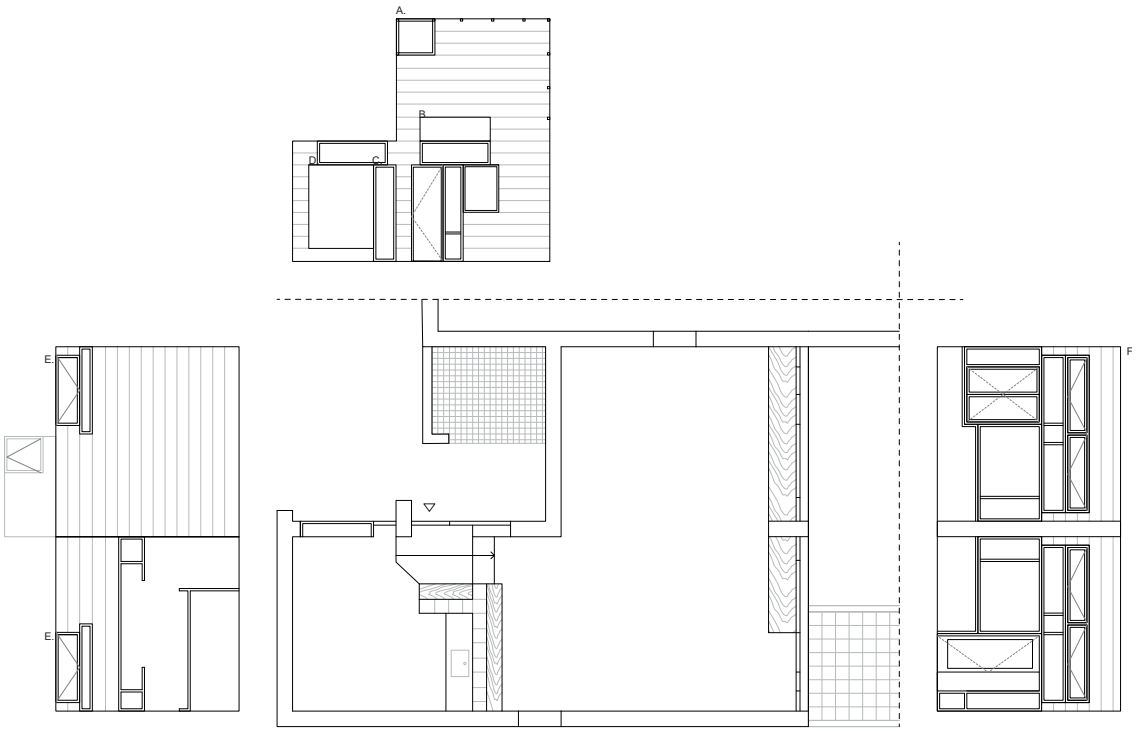


As cheaper and more efficient production systems were invented, the use of bigger panes of glass in windows became more common. With industrialisation, the use of standard sizes for windows gained popularity. However, in the 60s, bespoke windows were still being made. Though it required a different construction technique and instructions from the architect.

3.1 An inventory of all the windows in a typical classroom

First, the rooflight (Fig. 17, A) has the shape of a cube subdivided into different squares. It bridges the gap between the lower hall and the higher classroom. Second, there is the classroom entrance. It consists of an inverted L-shaped opening, with a solid door, a full-height vertical window, and a square window flush with the exterior wall (Fig.17, B). Above, there's a horizontal, vitrine-like display window, complemented by a frameless glass clerestory set flush with the interior wall (McCarter, 2015, p.141). Next to the entrance, a narrow, full-height window offers a view into the central hall (Fig.17, C). A wooden cabinet provides access to the display windows, a showcase of personal artefacts of the children to the school community (Fig.17, D) (Hertzberger & TU Delft, 1984, p.66). Third, inside the classroom, bridging the gap between the lower, sink area and the higher, classroom space, is a clerestory window (Fig.17, E). The outdoor wall has windows along its entire width. It is subdivided into two nearly symmetrical sections. One corner has a door, framed by two long windows, leading to the outdoor terrace. There are also wooden worktables built into to windowsill (Fig.17, F). The other corner has two lower windows, creating a seat on the inside. Above are two clerestory windows, the lower one projects outwards, providing a deep shelf for displaying objects and plants, and the other is openable and projects inwards (McCarter, 2015, p.141).

Figure 17- Floorplan classroom and interior walls, Montessori school, Delft



3.2 The skylight

The window frame of the skylight is made out of 9 by 9 cm “red wood”, pine wood with an oak glazing bead. Red class wood is a dimensionally stable softwood, as it has been artificially dried. The single glazing is attached to the pine wood frame with a galvanised steel profile using lead connection strips. The horizontal squares of glass are made out of wire-net glass, a type of safety glass and the vertical glass panes are made out of window glass. One of the glass squares is an openable, horizontally hinged window (Hertzberger, 25 juni 1963a) (Fig. 18).

3.3 The window looking into the corridor

The indoor window consists of 3 parts: an upper clerestory window, a lower clerestory window and a window and door at eye level. The upper clerestory window has an almost invisible window frame. The low and upper glass rebates are cast in the concrete using a metal profile. The glass pane is fastened on the sides using an oak glazing bead. The lower clerestory window is made with 4 by 12 and 4 by 4 cm pine. The shelf is made with two sheets of 10 mm multiplex fastened onto a 4 by 5 cm piece of pine wood. The frame for the door and the eye-height window are made out of 5 by 12 pine. The door sill is made out of beech wood (Hertzberger, 25 juni 1963b) (Fig.18).

3.4 The window facing the outdoors

Similar to the indoor window, this window consists of different elements of pine wood and oak glazing beads. The first clerestory window, protruding inwards, is made of 5 by 12 cm pine wood. There are two sash windows, opening to the inside of 4 by 6 cm. The second clerestory window, protruding outwards, is made out of 7 by 10, 4 by 7, 5 by 7 and 5 by 12 cm. The inside shelf is made with 10mm multiplex and 10 mm softwood fastened onto a 4 by 5 cm piece of pine wood. The windows at eye level are made with 5 by 12 and 6 by 12 cm pine wood. A lower window is made of hard glass. The door is from the Dutch carpentry factory Bruynzeel, it also has a granite sill (Hertzberger, 25 juni 1963a) (Fig.19).

The windows of the Delft Montessori school are made of a black painted pine. The skylight is crafted using a thicker profile of 9 by 9 cm than the indoor windows (4 by 4, 4 by 5 cm) and the outdoor windows (4 by 5 to 5 by 12 cm). Different types of glass are used depending on the function, such as wire-net glass for the horizontal panes of the skylight, hardened glass for the lower parts of the windows and window glass for the remaining parts.

Figure 18- Section and axonometry of skylight and indoor window, Montessori school, Delft

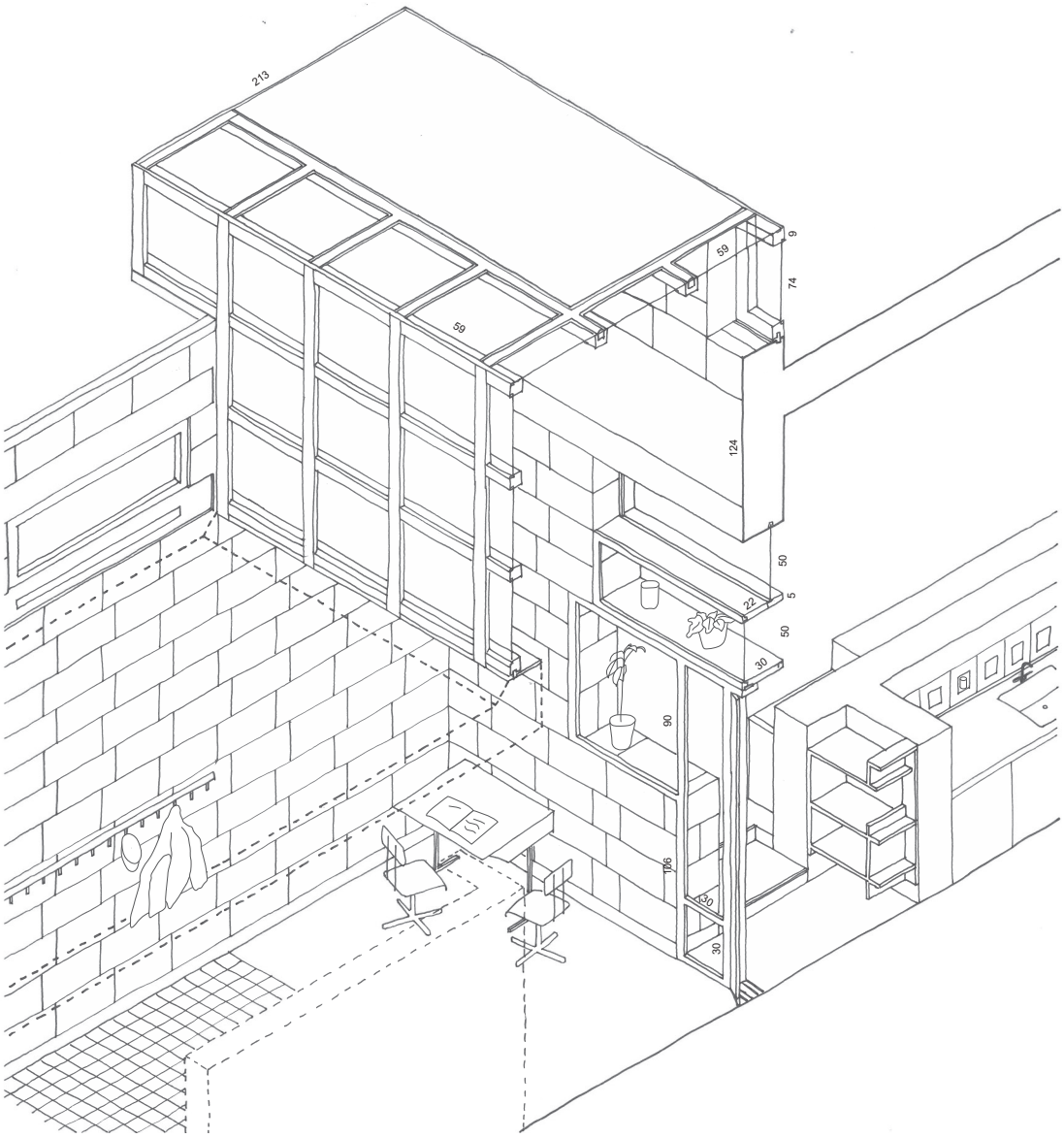
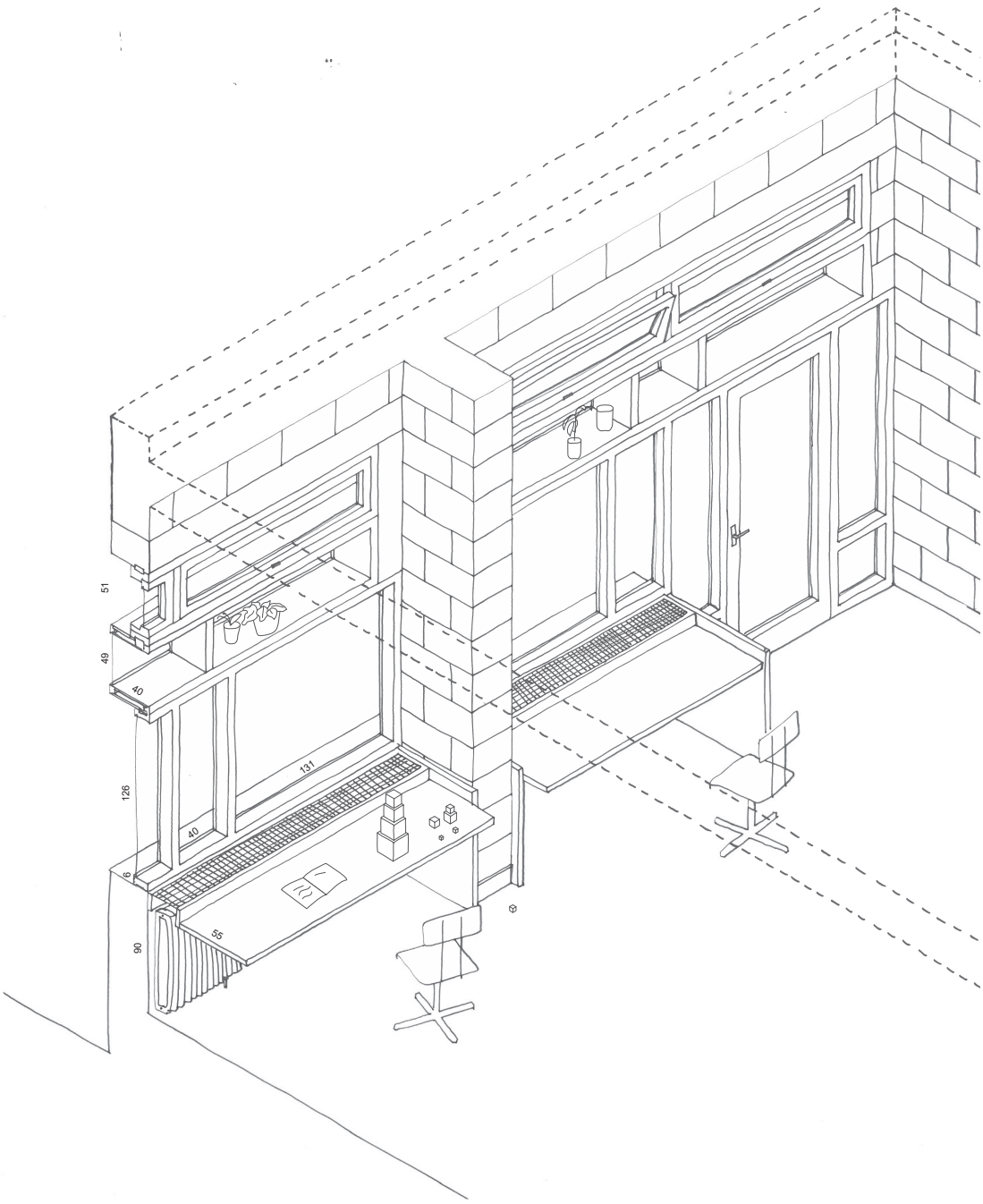


Figure 19- Section and axonometry outdoor window, Montessori school, Delft



4 Hertzberger's windows as a response to the industrial and cultural practices of the Montessori educational philosophy

4.1 Where do Hertzberger's windows stand between industrialisation and craft?

Changes in technology

The detailed drawings found in the archive feature the sizes of the rough-sawn timber needed, which is a common practice for handcrafted windows (Hertzberger, 25 juni 1963a,b) (Barry, 1958, p.21). Moreover, the amount of detailed drawings confirms that the windows of the Montessori school in Delft are not standard elements but were designed by Herman Hertzberger, specifically for the Montessori school.

The largest glass pane of the exterior window has a size of 114 by 129 cm. This is quite small, as at the time, window surfaces of up to 600 by 320 were available (Tsukamoto, 2023, p.216). The refusal to enlarge the window size can be linked to Hertzberger's preference for articulated windows, which can be manually opened and serve multiple purposes. The smaller window size also has a practical aspect. For example, the lower part of the windows, more prone to damage, is made of more durable and expensive toughened glass.

Network of production systems for windows

The windows are mostly made out of Swedish pine wood. The glazing bead is made out of oak, a more durable hardwood. This combination is economical as Swedish pine wood is inexpensive, and oak is a more durable but more expensive hardwood, which is needed for the glazing bead. The softwood window frames are inexpensive and therefore need to be painted. Detailed instructions on the treatment of the window frames after installation include: priming the frames, lime-painting them, filling in the holes and seams, and applying a final coat of primer and black paint (Gemeente Delft, augustus 1968, p.25). For the skylight, another type of wood is used: treated, red-grade pine wood. It is also a softwood but it is treated to be more dimensionally stable, which is needed for the structural stability of the cube shape. The glass used for the windows varies. Two types of safety glass are used: wire-net glass (6-8 mm), for the horizontal panes of the skylight, to keep the glass shards together in case of damage and toughened glass (4,5 mm), used for the lower parts of the windows, as it is sturdier and breaks into granular chunks. The other parts have 2,8 – 3,2 mm window glass (Hertzberger, 25 juni 1963a,b).

The doors were made by domestic companies such as Halbertsma, a Frisian company, and Bruynzeel, a company based in Zaandam (Gemeente Delft, augustus 1968, p.18). The archival drawings didn't detail the names of the companies that made the windows. However, the use of Dutch companies for doors leads us to believe that the same was done for the windows.

Although 20th-century industrialisation and modernism dictated a preference for standardised large windows with a delicate steel frame, Hertzberger's windows remain rooted in craftsmanship and detail, with use and practicality in mind. The bespoke nature of the windows means they are more labour and cost-intensive to produce than the ready-made solutions available at the time. However, the varying

wood and glass types according to function, and the cheaper softwood used for the window frames, testify to an economical and pragmatic approach to the production of the windows.

4.2 How do the windows respond to the regulations and norms for schools?

The direction of the light

In the studied classroom, there is natural light coming from three sides: directly from the outdoor window and the two upper clerestory windows on the opposite wall, and indirectly from the indoor window connected to the hall. The 1924 Bouwbesluit, requiring natural light to only come from one side of the classroom, is not applicable (Bouwbesluit 1924, art. 10, par. 1). The more recent Bouwbesluit kleuteronderwijs requires light coming from multiple angles (Bouwbesluit Kleuteronderwijs 1958, art.10). This approach is more in line with the design of the classroom. Although it is written with a rectangular classroom in mind, as it describes a classroom with four walls: the side, front, and back walls. Herzberger's design surpasses the requirements for the direction of the light, exemplifying his affinity for high sidelights and a multiplicity of options for natural light.

Height of the windows

Both indoor and outdoor windows have parts that go down to the floor, not conform to the regulations of neither the Bouwbesluit 1924, requiring the parapet of the windows to be set at 1 m above the floor (Bouwbesluit 1924, art. 10, par. 5) nor the Bouwbesluit Kleuteronderwijs 1958, of 0.40 m (Bouwbesluit Kleuteronderwijs 1958, art.10). Montessori schools often have a lower parapet than required, because contact with the outside world is seen as important (Spoelstra, 2009, p.53). The Montessori classroom is connected to other functions, such as a garden and an outdoor workspace, which demand lower windows. For the remaining outdoor windows, the window sill is set at 90 cm, to the eye height of children when seated.

The indoor window is set at 105 cm, much higher than the other windows in the classroom. This could be traced back to the regulations for the doors of the Bouwbesluit Kleuteronderwijs 1958, stipulating that the door must open outward and be fitted with a glass panel at 1.40 m, for the teacher to look through (Bouwbesluit Kleuteronderwijs 1958, art.11). Instead of using a door with a glass panel, Hertzberger placed a window opening next to it, even adding a window, that goes down to the floor, for a child to look through. This window is placed further away from the workspace to offer privacy and prevent distraction both inside and outside the classroom. The regulations are adapted and changed to fit both Hertzerbger's vision of the articulated classroom and the Montessori philosophy, promoting connection to the outside world.

Windows for natural ventilation

The regulations of 1924 show a concern for hygiene in the classroom. An example is the requirement that the upper windows had to allow for natural ventilation during lessons (Bouwbesluit 1924, art. 10, par. 6). These regulations prescribe the amount of openable clerestory windows, placed opposite each other. Furthermore, at least half of the total surface area of the lower windows in each classroom should be

openable (Bouwbesluit 1924, art. 10, par. 7). The Bouwbesluit Kleuteronderwijs 1958 specifies that at least half of the windows, divided among upper and lower, must be openable (Kleuterscholenbouw, 1958). Hertzberger's classroom conforms to the regulations for the number of openable windows. It can be noted, however, that one of the openable elements is a door that opens to the garden, which is not standard.

The key provisions of the regulations, such as natural light and ventilation, are carefully followed and often exceeded. This urge to excel and offer such a variety of fenestration could be explained by a desire for experimentation, in response to the restrictive Bouwbesluit of 1924. The regulations regarding the parapet are subverted and changed to fit both Hertzerbger's vision of the articulated classroom and the Montessori philosophy, promoting connection to the outside world. In certain cases, the regulations are ingeniously adapted to better fit both Hertzberger's and the Montessori ideals.

4.3 How do the windows serve as spatial tools to implement the Montessori philosophy?

Similarly to the articulated classroom, the windows are also articulated to enable various activities. The skylight simultaneously provides light for the hall, making it a space suitable for communal activities, whilst also offering the possibility of working outside the classroom (Fig.18). The skylight is a crucial element for the corridor and becomes a path through a landscape of islands of different workstations (Hertzberger, 2008, p.79). The indoor window similarly serves multiple purposes (Fig. 18). It provides a space outside the classroom that is separated from the main work area with a door, providing a calmer, more introverted place to work. The long window next to the door connects it visually to the classroom. A picture reveals its intended use (Fig.20): a girl inside the classroom checks on a pupil working outside. The higher window, at the eye level of adults, is meant for the teacher to keep an eye on the students working outside the classroom. The outdoor windows similarly serve numerous uses. A built-in desk provides a workspace in connection with the outside (Fig.19). The door offers the possibility of working in the garden. The bottom clerestory window functions as a built-in shelf to display personal items or offer a resting place for a plant, as it is a common Montessori task to take care of your plant (Hertzberger, 2008, p.38). The top clerestory window is meant for ventilation.

Figure 20- Indoor window and entrace to the classroom, Montessori school, Delft, Herman Hertzberger - 1966

The conflict between concentration and distraction is a leading component in Hertzberger's design for the school, as this is seen as a pivotal element in Montessori architecture (Lawrence & Stæhli, 2023). This tension is resolved by spatial means, namely "views and cover" (Hertzberger, 2008, p.80). It can be seen in the differentiation of the working spaces using windows. The skylight and indoor window frame a working space (Fig.18). To ensure concentration, the indoor window doesn't give a direct look into the classroom; it looks onto the shelf delimiting the sink area. Similarly, on the other side, it doesn't give a direct outlook into the hall, but into the antechamber with the cloakroom. The skylight, providing concentrated light, has a focusing effect (Fig.13). In contrast, the working space along the outdoor window is more open. The window has a direct view of the garden and on the other side into the classroom (Fig.19).

The admission of daylight is used as a tool to differentiate spaces (Lawrence & Stæhli, 2023). As a result of the height difference, the cube-like shape of the skylight is not visible from the hall and resembles a beacon of light in an otherwise dark area (Fig.10). The clear contrasts between light and dark serves as a powerful tool in wayfinding, defining the entrance to the classroom (Hertzberger, 2008, p.83).

The windows are articulated to enable various specific activities. They are employed as tools to differentiate areas for concentration and social interaction. From their spatial articulation to their specific articulation, Hertzberger's design of the windows is a testimony to his deep understanding of the Montessori education.

Discussion

The goal of this history paper was to unravel unknown facets of Hertzberger's design for the Montessori school in Delft and the historical context in which he was working, by zooming in on a specific part of a building, the window.

The focus on a singular aspect made it possible to carry out highly detailed research in a short time. For example, it made it possible to quickly look through a vast amount of archival material. On the other hand, finding specific information such as the production system networks of windows in the Netherlands in the 60s, or the specific building regulations for schools, proved to be difficult. The Hertzberger archive mainly consists of drawings, so very little information was found on possible manufacturers or specific demands of the Montessori association. Moreover, not much is published on these topics that is readily available at the library.

Tracking down the Bouwbesluit of 1959 was difficult. As it is an older publication, and not digitised yet, nor the archivists that were contacted from the Rijksarchief, nor the librarians from the TU Delft were able to point in the right direction. The Bouwbesluit is scarcely mentioned in the literature on schools in the Netherlands, and none use the Bouwbesluit of 1959 as a primary source. An attempt at tracking down the source quoted in Boersma (1996), The 4th ICS Bulletin, published by Stichting Informatiecentrum voor Scholenbouw in 1966, also failed. Only issues starting from 1970 are available in the archives of the University library and the publisher, now called ICS adviseurs. The missing piece of information, that all laws, including the Bouwbesluit, are published in het Staatsblad, was found too late.

To further the research, architects who were practising in the Netherlands in the 60s could be contacted to collect information on the production of windows and the building regulations of schools.

Doing this research, I expected Hertzberger's windows to be admirably crafted and to beautifully fit the architecture of the school. The archival drawings, however, revealed the vast amount of detail and thought that went into their design. Furthermore, this paper uncovered how each window is crafted for a specific use related to the Montessori education philosophy. This relates to the spirit of the time, a reaction against the standardisation linked to modernist ideals and increasing industrialisation. In addition, more loose regulations and the diminished pricing of windows meant there was more room for experimentation.

For follow-up research, it could be interesting to look at the windows of the later schools built by Hertzberger. This would give a broader scope to compare the different design solutions. It would enable us to gauge the influence of the type of school and time, facilitating a more comprehensive view of Hertzberger's attitude towards fenestration.

Conclusion

This research focused on the design practices of Herman Hertzberger from the perspectives of production system networks and cultural practices within the Montessori educational philosophy, by studying a specific example and element: the windows of the Montessori school in Delft.

The Delft Montessori school of Herman Hertzberger is an example of one of the few hall schools of the 1960s, which succeeded in aligning the architectural and educational concepts almost seamlessly. The school fits all the required criteria of a typical Montessori school, whilst improving on the Dutch examples of the time. The combination of the requirement for extra services in the classroom and architectural detailing, results in what Hertzberger calls the articulated classroom. The windows play a pivotal role in defining these different workspaces by creating different atmospheres.

Instead of embracing the modernist inclination towards standardisation and industrial uniformity, Hertzberger's windows remain deeply rooted in craft and detail. The bespoke nature of the windows, reflected in the intricate details related to their use and varying wood and glass types, exhibits a careful negotiation between function, cost and durability. The choice for highly articulated wooden windows, at a time when larger steel-framed windows were in fashion, testifies to Hertzberger’s preference for tactile and articulated design and to the Montessori ideals of independence and self-directed learning.

The school was constructed following the provisions of the 1924 Bouwbesluit, which severely restricted the layout and fenestration possibilities for schools. At the same time, more efficient production systems of glass were invented, which lowered the overall cost of windows. Hertzberger’s fenestration can therefore be seen in the light of renewed experimentation. From a regulatory standpoint, Hertzberger’s windows sometimes creatively interpret the building regulations to better fit both Hertzberger’s and the Montessori ideals. The lower parapets, which are not in line with the Bouwbesluit, are a common deviation among reform schools. However, the key provisions, such as natural light and ventilation, are carefully followed and even exceeded.

Most remarkably, the windows serve as a spatial tool in Hertzbeger’s articulation of the Montessori learning environment. The differentiation of views, varying degrees of natural light and enclosure shape a dynamic learning environment suitable for a variety of activities, both individual and in groups. From worktables, seats and shelves built into the windows to the possibility to display the plants the children are tasked to take care of, the articulation of the windows exhibits a deep understanding of the Montessori educational philosophy.

Hertzberger’s window design transcends the regulatory requirements to embody an architectural language tailored to the Montessori education. It is a skilful mediation between craft making use of humble materials and progressive educational ideals.

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