PAPER

Aspiring Scientific Design: Hannes Meyer and Hans Wittwer's Petersschule Project and Daylighting Scholarship

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This paper looks at the advancement and implementation of daylighting calculations in architectural design during High Modernism. Particularly, it analyzes the engineering and architectural discourses on daylighting in the 1920s with respect to the arguments they delivered for healthy school environments. Using the case study of Hannes Meyer and Hans Wittwer's famous 1926 project for the Petersschule in Basel, Switzerland, the paper intends to show the modernist stretch between scientific abstraction and design synthesis. In the 1920s, declaring good daylighting design as the first objective for a healthy school was not a new topic. For decades, school regulations had included recommendations for window designs, class room orientations, window-to-floor ratios, and sky-view angles, among others. With advancements in lighting science, for example the definition and measurement of illuminance, such empirical knowledge was increasingly disapproved in favor of more mathematical approaches to design. Meyer and Wittwer's use of the "calculation procedure after Higbie and Levin" exemplifies how architects attempted to incorporate the state-of-the-art knowledge of daylighting in design. Henry Harold Higbie and A. Levin published their calculation methods of daylight intensity in the Transactions of the Illuminating Engineering Society in May 1925 and March 1926, only shortly before the Petersschule competition. Analyzing the calculations, this paper tries to retrace how they influenced the design. Since Meyer and Wittwer also referred to several rules of thumb, one can speculate whether the architects' empirical knowledge had initially helped them developing their design, while calculations served as later verification.

In April 1927, the same month in which Hannes Meyer (1889-1954) started his work as professor of architecture at the Bauhaus, the journal *bauhaus* published his and Hans Wittwer's (1894-1952) competition design of the Petersschule in the historic center of Basel, Switzerland (fig. 1). The design became a famous scheme of the modern movement. Rather than presenting the competition drawings, the page showed a revised project on the upper left quarter of the page, with a second-floor plan in the middle of the drawings, a cross section and portion of the east façade above it, and an axonometric drawing of the school next to a diagram with the title "theoretic illumination curves for

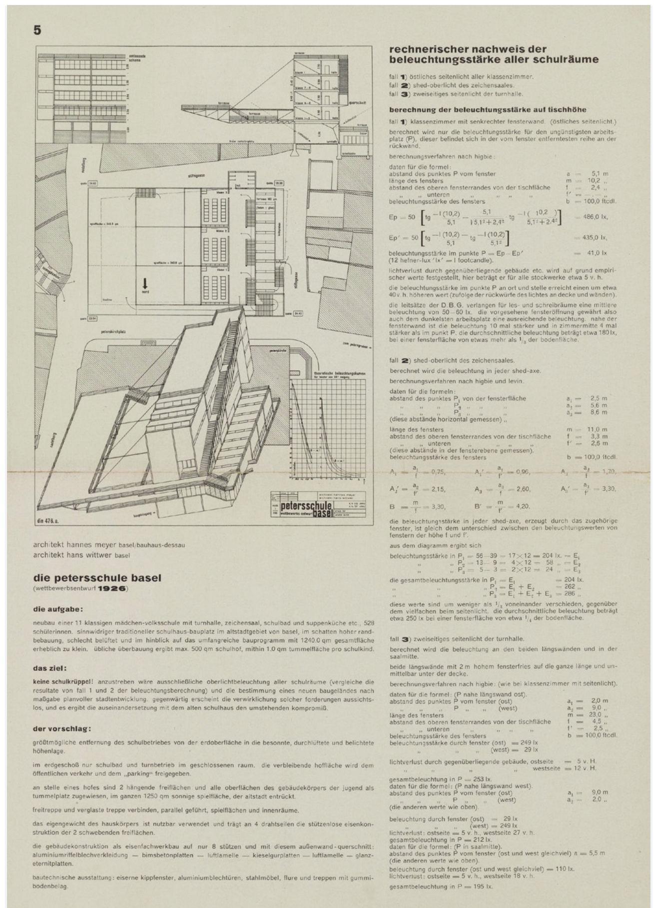

Figure 1: *bauhaus* 2, 1927, page 5.

windows tilted 60°" underneath.[1] The plan is presented with a north-arrow pointing downward, possibly to better align with the section and axonometric drawing and thus allow for improved readability of the drawings. On the lower left corner, the drawing says "din 476.a," which refers to the German standard of paper formats that the *Normenausschuss der deutschen Industrie* had issued for the first time in 1922 and which was quickly adopted by other countries.[2] Below the drawings is a pamphlet-like description of the design, in which Meyer and Wittwer claim daylighting to be the first objective for healthy schools. They accuse the client of having chosen a "nonsensical traditional school building site" that didn't allow for best daylighting, which, in their view, was "exclusive top-lighting of all school rooms."[3] Already on the original competition board they had complained that "[s]hed skylights had to be abandoned for all school rooms (except drawing room) because of the limited space and the regress to the worse sidelight had to be done."[4] Most unusual for a design presentation is the right column of the page, which is occupied by illuminance calculations for three rooms in the school. The presentation in din-format and the calculations convey the intent of an objective precision that meets technical, engineering, and scientific standards. It can be read as an agreement with Walter Gropius's 1923 Bauhaus agenda "Art and Technology—a New Unity" and an emblematic forecast of the years ahead of the Bauhaus. Looking closer at the calculations, the following paper asks whether the project can serve as what Klaus-Jürgen Winkler called a "demonstration means for the aspired partnership between architect and science"?[5] Do we follow Michael Hays hypothesis that the project "induces an experience of the world increasingly as a succession of completed material substances seemingly operating through automatic mechanisms (the diagrams and calculations)"?[6] Or is the project rather an example of the "radical search for objectivization and use-orientation," as Philipp Oswalt pointed out?[7]

MEYER'S AND WITTWER'S DAYLIGHTING FOCI

Meyer and Wittwer started their office together in April 1926. Their short collaboration between 1926 and 1929 resulted in two of the most famous competition projects of high modernism—the Petersschule in Basel and the Palace of the League of Nations in Geneva—and the similarly famous built project of the Federal Trade Union School in Bernau near Berlin. Both architects had a deep interest in science and technology as a basis for architecture. Meyer's 1926 pamphlet "The New World" praises newest technical achievements, such as the airship 'Norge,' the Zeiss planetarium at Jena, and the rotor ship by Anton Flettner as "outcomes of extreme precision in thought" and as "striking evidence of a continuing scientific permeation of our environment." Comparing the developments in the sciences and the arts, he asserted that the "artist's studio becomes a scientific and technical laboratory, and his works are results of acuity of thinking and inventive power." Stating that "[b]uilding is a technical not an aesthetic process," he includes "insolation (sun exposure), natural and artificial lighting," among others, as "the determining lines of force."[8] Also Wittwer expressed, in less dramatic words, the need of using "the findings of science to solve architectural tasks."[9] His interest in daylighting became manifest in an earlier competition project for the Geneva-Cornavin station, which he had developed under the title "Shed" in 1925, for which he stated that the "roofing is projected with least light loss."[10] For the competition project of a brewery building in the core city of Basel, submitted in early 1926, Wittwer apparently undertook daylight calculations.[11] Wittwer's son, Hans-Jakob Wittwer, speculated that Wittwer's brother-in-law, Erwin Voellmy (1886–1951), had supported him in the calculations, as he did in the later project of the Palace of the League of Nations, there with a focus on acoustics.[12] Voellmy was trained in mathematics, physics, and geography, and had an acknowledged career as a math teacher, aside from being the Swiss chess master in 1920 and 1922.[13] Wittwer's interest in science and technology is also manifest in his teaching of the technical integration courses at the Bauhaus from 1928 onward, including "acoustics, light, heat and installation."[14]

THE ARTICLE'S DAYLIGHT CALCULATIONS

The Petersschule competition took place in the fall of 1926, with 104 entries. Meyer and Wittwer's design made it only to the first round.[15] The design's enormous gesture of cantilevering two schoolyards by means of four steel cables, as shown in the axonometric drawing and section of fig. 1, would suggest the presentation of structural calculations. In the journal, however, the authors argue for a design that is derived from good daylighting. For the shady site, Meyer and Wittwer came up with the "proposal: maximum distance of the school operation from the ground surface into the insolated, ventilated and illuminated altitude."[16] They argued that a hygienic design would necessitate to elevate the schoolyard closer to sunlight and this would justify the suspended structure.[17] Thus, the daring steel structure is presented only as a second consideration, deduced from daylighting as a first objective to achieve a hygienic environment. Consequently, rather than presenting structural calculations to underscore the structural soundness of the design, the description focuses on the aspect of daylighting in schools. However, instead of presenting evidence of the site's inadequate daylight exposure, the calculations focus on daylighting of the school's interior rooms.

The article's right column with its title "calculated evidence of the illuminance of all school spaces" presents three cases: "case 1) eastern sidelight of all classrooms. case 2) shed-skylight of the art room. case 3) two-sided sidelight of the gymnasium." The authors based their calculations for case 1 and 3 on the "calculation procedure after Higbie" and case 2 on the "calculation procedure after Higbie and Levin." This proposes that the authors were well aware of the state-of-the-art knowledge in daylighting of their time, as Henry Harold Higbie (1882–1947) and A. Levin (life dates unknown) published their daylight calculation methods in the *Transactions of the Illuminating Engineering Society (IES), i*n May 1925 and March 1926, only shortly before the competition.[18] Higbie was a professor of electrical and mechanical engineering at the University of Michigan from 1905 to 1947 and the president of the American *IES* from 1926 to 1927. A. Levin was a graduate student of electrical engineering at the University of Michigan from 1924 to 1925. Higbie and Levin's method is recognized today as "the first exact and perfectly general solution to give the intensity of light at any point of the room from a window of any dimension. This formula is the basic formula for successive simple and complex daylight analysis methods."[19] How Higbie's and Levin's theories made it to Meyer and Wittwer is an open question, as no competition consultant was listed and Meyer's and Wittwer's estates at the gta Archives do not include Higbie's and Levin's publications. Erwin Voellmy could have been a probable support. In addition, since the building design's dimensions were changed for the *bauhaus* presentation, the calculations were either adapted or, as could be speculated, even done for the first time on this occasion.

Zooming further in, we learn that for all three cases illuminance levels E are calculated at table height/working plane, a predetermination still quite new at the time of the publication. The sizes of the rooms and windows and the location of the windows are provided. As is shown in the drawings, the windows span the entire length of the walls (for the class rooms and gymnasium) and the entire width of the roof (for the art room), which already suggests that daylighting and illuminance levels will be high. The authors state that for the first case, the classroom with eastern windows, "only the illuminance for the least favorable work place (P) will be calculated, which is located in the row furthest away of the window at the rear wall." For the second case, the art room with skylights, they calculate illuminance levels for three points within the room. And for the third case, the gymnasium with eastern and western windows, they present results for locations close to the west and east walls and the middle of the room.

daten für die formel:

abstand des punktes P vom fenster	a =	5,1 m
länge des fensters	m =	10,2 ,,
abstand des oberen fensterrandes von der tischfläche	f =	2,4 ,,
,, ,, unteren ,, ,, ,, ,,	f′ =	—.— ,,
beleuchtungsstärke des fensters	b =	100,0 ftcdl.

$$Ep = 50 \left[tg^{-I} \frac{(10,2)}{5,1} - \frac{5,1}{\surd 5,1^2+2,4^2} \cdot tg^{-I} \left(\frac{10,2}{5,1^2+2,4^2} \right) \right] = 486,0 \text{ lx,}$$

$$Ep' = 50 \left[tg^{-I} \frac{(10,2)}{5,1} - tg^{-I} \frac{(10,2)}{5,1^2} \right] = 435,0 \text{ lx,}$$

beleuchtungsstärke im punkte P = Ep – Ep′ = 41,0 lx
(12 hefner-lux ′lx′ = I footcandle).

Figure 2: Detail from figure 1: Calculation for case 1.

Fig. 2 shows a detail of the page, zooming into the formula and data of the first case, with a being the "distance of the point P from window," m the "length of window," f the "distance of the upper window edge from table surface," f' the distance of the "lower" window edge from table surface, and b the "illumination value of the window." While the distances are easy to understand, the factor b might need some clarification. It appears in all three calculations and explains that the window is interpreted as a laminar light source with large dimensions. More specifically, Higbie and Levin call the window the "luminous surface," assuming "the source of light to be rectangular in shape, whether it be a window opening through which sky is seen, or a portion of the ceiling or side-wall surface."[20] Higbie and Levin specify b as the "brightness per square foot through the window" or the "uniform brightness b candlepower per square foot."[21] That said, the calculation abstracts from specific sky conditions, such as direct sunlight, but rather assumes "[all] portions of this rectangular light source […] to be of the same brightness" and "the light entering through the window" as "perfectly diffuse."[22] In the Bauhaus publication, b equals "100,0 ftcdl," and while the unit is mislabeled as footcandle rather than candlepower per squarefoot (today candela per squarefoot, cd/ft^2), the magnitude is consistent with Higbie and Levin and still used today.

$$E_P = \frac{b}{2}\left[tan^{-1}\left(\frac{m}{a}\right) - \frac{a}{\sqrt{a^2+f^2}}\, tan^{-1}\left(\frac{m}{\sqrt{a^2+f^2}}\right)\right]$$

Figure 3: Equation from Higbie 1925, page 442. Similar in Higbie/Levin 1926, page 280.

The formula for the illuminance level Ep that Meyer and Wittwer present below the list of data (fig. 2) is quite similar to the one found in Higbie 1925 (fig. 3) and Higbie/Levin 1926. With the latter publications at hand, we can figure out that in Meyer and Wittwer's equation, the factor b is used at the beginning (100/2 = 50); tg^{-I} stands for the arctangent; the parentheses are for the entire fraction (not only the numerator); and the equation uses two different fonts for the number 1. Some of these issues might have been typesetting problems, as the Bauhaus journal was not specialized on printing mathematical equations. However, comparing Meyer/Wittwer's equation with Higbie's, it is unclear why the former misses one of the two root symbols that the latter has. It is also unclear why Meyer/Wittwer calculate Ep', which is a calculation step not presented in Higbie and Levin. Entering the data into the Bauhaus journal's formulas and using radians rather than degrees[23] lead to similar results to the ones presented, which are Ep = 486 lux and Ep'=435 lux. The next calculation step, shown at the bottom of fig. 2, is a simple subtraction: Ep-Ep'=41 lux. However, 486 minus 435 equals 51, which presents an avoidable error that reduces the cogency of the calculation. On the other hand, entering the data in Higbie's original formula as shown in fig. 3 and converting the result leads to about 85 lux.

Higbie's formula is in foot-candle, and Meyer/Wittwer convert their results to "hefner-lux," stating that 12 hefner-lux equal 1 foot-candle (this conversion is used in the entire paper). Mixing units was not unusual at the time and resulted from two problems. The first problem for engineers was to define a standard light source (candles made from wax, spermaceti, paraffin, etc., or lamps fueled with pentane, amyl acetate, etc.) and related standard luminous intensity, which resulted in units such as "British candle," "French Bougie," German "Vereinskerze," or German "Hefner-Kerze." The *International Photometric Commission* (CIE) came up with the internationally-agreed unit of an "international candle" in 1911. However, the German "Hefner-Kerze" remained to be considered the most precise light source of the time, to which even British and other European standards referred.[24] The second problem dealt with the use of metric versus British imperial/US customary units. When calculating illuminance, engineers applied feet or meter to the above units of international candle and Hefner-Kerze, which resulted

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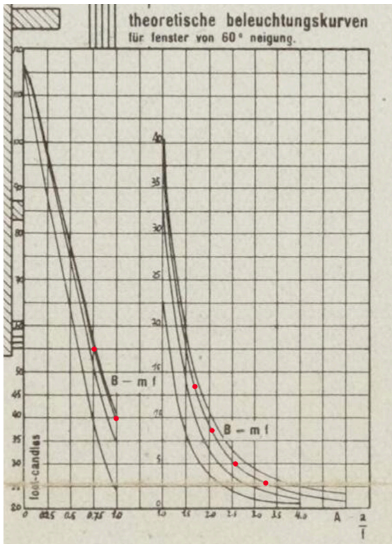

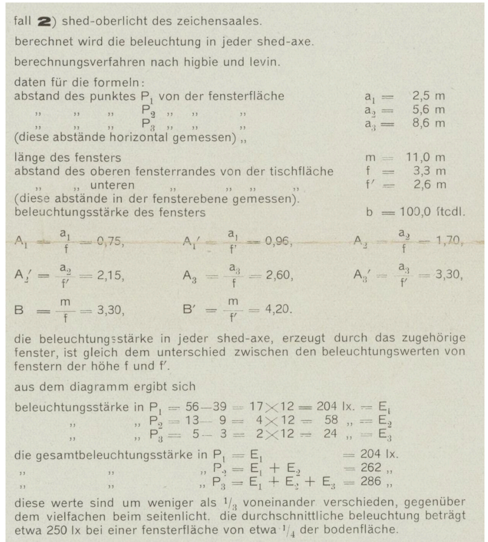
fall 2) shed-oberlicht des zeichensaales.

berechnet wird die beleuchtung in jeder shed-axe.

berechnungsverfahren nach higbie und levin.

daten für die formeln:

abstand des punktes P_1 von der fensterfläche	$a_1 =$ 2,5 m
,, ,, ,, P_2 ,, ,, ,,	$a_2 =$ 5,6 m
,, ,, ,, P_3 ,, ,, ,,	$a_3 =$ 8,6 m
(diese abstände horizontal gemessen) ,,	
länge des fensters	$m =$ 11,0 m
abstand des oberen fensterrandes von der tischfläche	$f =$ 3,3 m
,, ,, unteren ,, ,, ,, ,,	$f' =$ 2,6 m
(diese abstände in der fensterebene gemessen).	
beleuchtungsstärke des fensters	$b = 100{,}0$ ftcdl.

$A_1 = \frac{a_1}{f} = 0{,}75$, $A_1' = \frac{a_1}{f'} = 0{,}96$, $A_2 = \frac{a_2}{f} = 1{,}70$,

$A_2' = \frac{a_2}{f'} = 2{,}15$, $A_3 = \frac{a_3}{f} = 2{,}60$, $A_3' = \frac{a_3}{f'} = 3{,}30$,

$B = \frac{m}{f} = 3{,}30$, $B' = \frac{m}{f'} = 4{,}20$.

die beleuchtungsstärke in jeder shed-axe, erzeugt durch das zugehörige fenster, ist gleich dem unterschied zwischen den beleuchtungswerten von fenstern der höhe f und f′.

aus dem diagramm ergibt sich

beleuchtungsstärke in $P_1 = 56-39 = 17 \times 12 = 204$ lx. $= E_1$
,, ,, $P_2 = 13-9 = 4 \times 12 = 58$,, $= E_2$
,, ,, $P_3 = 5-3 = 2 \times 12 = 24$,, $= E_3$

die gesamtbeleuchtungsstärke in $P_1 = E_1 = 204$ lx.
,, ,, ,, $P_2 = E_1 + E_2 = 262$,,
,, ,, ,, $P_3 = E_1 + E_2 + E_3 = 286$,,

diese werte sind um weniger als 1/3 voneinander verschieden, gegenüber dem vielfachen beim seitenlicht. die durchschnittliche beleuchtung beträgt etwa 250 lx bei einer fensterfläche von etwa 1/4 der bodenfläche.

Figure 4: Details from *bauhaus* page, presenting the illumination determination on a working plane in the art-room employing shed-skylights tilted 60°. Red marks on diagram by author.

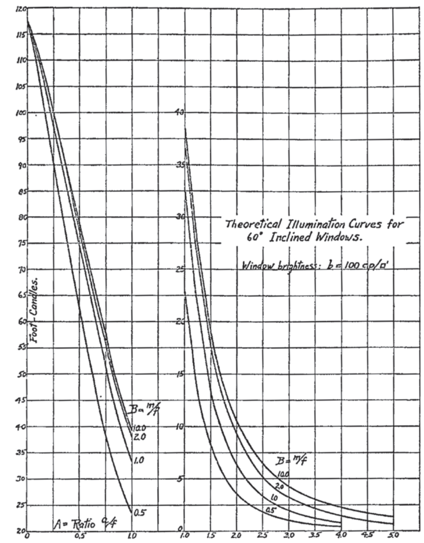

Figure 5: "Theoretical Illumination Curves" in Higbie/Levin 1926, page 299.

in a myriad of units, among them candle-foot, candle-metre, foot-candle, metre-candle, metre-hefner, lux, and hefner-lux. Calculations had to convert units not only for luminous intensity, but also for illuminance. These issues were still unsolved in the times of the Petersschule competition.[25]

In the concluding text under case 1, Meyer and Wittwer state that the result must be reduced by 5 per cent because of the "light loss from opposite buildings etc. […] based on empirical values" and then increased by 40 per cent because of the reflections from ceiling and walls. Both factors were not specified in the publications by Higbie and Higbie/Levin, which reveals that Meyer and Wittwer based their calculation on additional, unmentioned references. Using the 41 lux from above, the final amount is about 55 lux—just as much as the *German Lighting Society (Deutsche Beleuchtungs-Gesellschaft)* "D.B.G. demands for reading and writing rooms" as a "middle illuminance of 50-60lx." Using 486-435=51 lux, the result would be about 75 lux. And taking Higbie's original formula, which works without Ep' and coefficients for light loss and interior reflectances, the result of 85 lux would be slightly higher. In either case, the illuminance level of 50-60 lux recommended by the D.B.G. is roughly ten times lower than what is recommended today, which might reveal that expectations for adequate daylighting were quite different at that time. In lighting science, calculating daylight in rooms came out of, or was only a second step after, calculations for artificial lighting. At the turn of twentieth century, when calculations for artificial lighting evolved, people were still used to reading close to a candle or petroleum lamp, many of them providing one or only a few foot-candles. Albeit the fact that electrical incandescent lamps were well developed in the 1920s—the year 1923 celebrated the fiftieth anniversary of the Edison lamp—less than a third of the households in Berlin had electrical lighting at that time. Therefore, expectations for illuminance levels were naturally much lower and these expectations might have been adopted in the evolving daylighting calculations.[26]

Also the third case—for the gymnasium—uses the calculation "after Higbie." Calculation steps are not repeated and the authors provide the following results: for a point close to the eastern wall 253 lux, to the western wall 212 lux, and in the middle of the room 195 lux. All of them are about three to four times higher than recommended by the D.B.G. for reading and writing.

The second case, the saw-tooth skylight, takes a different approach, as it uses the diagram presented on the journal page (see fig. 1). Details are presented in fig. 4. Different from the other cases, the information given here allows, to a certain extent, to follow the presented calculation path. First, a similar list of data is provided as in the other cases, that is diverse distances (a, m, f) and the window brightness b. A ratio A between a (distance of P from window) and f (distance between upper window edge from table surface) and a similar ratio A' between a and f' (distance between lower window edge from table surface) are calculated for three different points P_1, P_2, and P_3 located "in each shed axis." The ratios A and A' are represented on the x-axis of the diagram, while the y-axis represents illuminance levels in foot-candles. In addition, a ratio B is presented between m (length of window) and f, and respectively B' between m and f'. In the diagram, the curves represent B and B'.[27] We do not know, why four curves are presented, but since we have the results of the calculation, we can work backwards, mark the results in the diagram (see fig. 4, marks from author), and see that they approximate to the second top curve. Only looking at Higbie/Levin's same diagram provides insight that the curves stand for B equal to 0.5, 1.0, 2.0, and 10 (fig. 5). Therefore, the second top curve (B=2) is the closest to Meyer and Wittwer's B and B' (3.3 and 4.2).

With the diagram, A and A' and B and B' at hand, one can (1) find the intersections from a calculated A on the x-axis and a curve and (2) determine from this intersection on the y-axis the illuminance level in foot-candles for the particular location (for which A was calculated). Meyer and Wittwer specified for the three different points 204, 262, and 286 lux. The results are overall higher than the results for the side-lighting in the regular class rooms and present a relatively even light distribution throughout the room, which is the ideal for an art room. The results might also explain why Meyer and Wittwer claimed top-lighting to be superior and that the best school lighting would be exclusively top-lighting in all classrooms. Such claim had already been made earlier, for example by P.J. Waldram in 1910.[28]

CALCULATIONS, RULES-OF-THUMB, AND DESIGN

Looking at the analysis so far, Meyer and Wittwer's presentation can be interpreted as a pioneering work of daylighting calculation in architectural design, which however, with respect to its typesetting and calculation mistakes, leaves the claim of "extreme precision," quoted at the beginning, unfulfilled. A much larger problem seems to be that the results are presented as showing a true lighting condition without acknowledging their abstractness. The calculation is based on a uniform light source, which does not present a real daylight condition. In addition, Higbie already points out that "there are numerous very variable factors influencing the natural illumination," which makes it "impossible to estimate accurately." Such factors are, among others, "clouds […] smoke or vapor from nearby chimneys […] Shadows from nearby buildings. Reflections from building fronts and roofs […] materials piled within a room. Shading due to bins, partitions, structural work […] Absorption of light due to glass in windows, to window casements and to sash structures, […] dirt accumulated on the glass […] glare reducing coatings put upon the glass." He concludes with respect of the method's precision that the neglect of these factors "makes the science of daylighting inevitably much less exact than that of artificial lighting."[29] By contrast, Meyer's and Wittwer's techno-scientific positivism seems to be evident in their taking the results as fact when concluding from the calculation that "the proposed window opening allows the darkest work place a sufficient illumination." While using the calculation as proof is questionable, its main benefit is rather that it allows a methodological basis of universal communication on which designs could be compared. Once experts are in agreement that a specific method creates a kind of benchmark, this method can be utilized to evaluate a design concept. Architects without such a method at hand would either justify their designs with "experience" and "authority" or would not justify their designs at all. Trying to critique this attitude, Wittwer stated that "[t]he result of scientific insight is for us people a truth, valid for all, binding. The result of intuitive insight is for us people not an all-valid truth, but a manifestation of a moment."[30] However, only by acknowledging that the calculations are abstract and do not replicate the actual daylight situation could his argument hold.

It is not the calculation that makes us confident that the proposed design provides ample daylighting. Meyer and Wittwer present other factors in their article that, one can hypothize, seem sufficient for coming to an equivalent precision and design outcome. One of it, the window-to-floor area ratio (WFR), is mentioned for two rooms and can be determined for the third one: In the class room "the window area is a bit larger than a third of the floor area"; in the art room the "skylight area is about a quarter of the floor area," and for the gymnasium, the window area is again more than a third of the floor area. The WFR was well known at the time. Summarizing recommendations for buildings and specifically for schools, P.J. Waldram claimed in 1910 that an "average architect […] knows that the window space of every room should be at least 1/10th of the floor space—text books written 100 years ago will tell him that—and he probably knows that the same proportion in schools should approximate to 1/4th."[31] The ratios in the Peterschule project exceed these recommendations, and since the design also followed other common design knowledge, such as favoring windows with horizontal proportions and placing these high in the wall, it seems obvious that the project provides daylighting far above a set minimum standard. Another rule-of-thumb is mentioned in a "tentative 'Code of Lighting School Buildings'" stating that "no work space is more distant from the window than twice the height of the top of the window from the floor."[32] Assuming that Meyer and Wittwer's window head is about 3.1m above the floor (table height 0.7m plus window height 2.4m), the table furthest away from the window could be 6.2m, however it is only 5.1m away and thus fulfills easily the recommendation.

However, rules-of-thumb were in low regard not only for Meyer and Wittwer, but for many architects and engineers. For example, Wendell Brown stated that "the designer must be unfettered by 'rule-of-thumb,' sentiment, or prejudice if he is to give the facts their proper weight in the ensemble."[33] Disesteeming rules-of-thumb had started in the early days of daylight science, even worked as a handy argument to justify daylight studies. As early as 1908, the *Journal of the Society of Architects* complained that architects were "guided in this important matter by guesswork only, or at the best by the application of approximate empirical rules which do not vary with varying conditions. The aspect of the window, its shape, the solid angle subtended in the clear sky visible from it, the colour of the opposing walls, and the interior decoration all affect its illuminating power, but so completely has the science of illuminations been ignored hitherto, that not one architect in a hundred, probably not one in a thousand, would know how to calculate the additional window space required to afford equal illumination under adverse conditions." Considering Higbie's 1925 state-of-the-art calculations above, such demands seem quite unrealistic even for lighting engineers of the time. However, the article continues that "[a]rchitects need now, and will need even more in the near future, to justify their plans before such [architectural competition] committees with regard to illumination as in other respects, and in terms certainly more exact than are in general use at present."[34] This comment anticipated Meyer and Wittwer's illumination calculations for the Petersschule competition one and a half decades later.

It would have been rather difficult to repeat the calculation based on the *bauhaus* journal's article, albeit one could claim that architects would still have received some understanding of daylighting components. The rudimentary calculations fit to the other presentation forms of the design, all of which are incomplete, but provocative: there is only one floorplan, one partial elevation, and a text that refuses detailed explanations in favor of statements like "no school cripples." This makes the drawings, text, and calculations communicate in the same manner as a manifest of the prevailing techno-scientific positivism of the time. Returning to the question raised at the beginning, whether the Petersschule project's design process can be read as an "automatic mechanism" of "diagrams and calculations" (Hays), the response must remain negative. Nevertheless, the presentation of the daylight calculations in the *bauhaus* journal can certainly be read as a "search for objectivization" (Oswalt).

It seems that the calculation method has never received more prominence in architectural venues than in the *bauhaus* journal. No other publication could be found so far, in which architects used the Higbie/Levin calculations for evaluating daylight conditions in rooms. However, as we know a hundred years later, in which we saw the illuminance calculations' road to success, we can understand that the Petersschule presentation in the *bauhaus* journal was ahead of its time.

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ENDNOTES

1. The original ink drawing in the format 59.1 x 42cm (DIN A 2) mounted on cardboard is at the Bauhaus Dessau Foundation Archive.
2. The standard paper formats are used today in almost all countries of the world except the US and Canada.
3. The translation in *bauhaus journal 1926–1931 facsimile edition,* Berlin: Lars Müller 2019, was not entirely followed in this paper for the purpose of providing a more direct translation of the original text.
4. The original board is in the gta Archives at the ETH Zurich.
5. Winkler, Hans-Jürgen, *Der Architekt hannes meyer. Anschauung und Werk*, Berlin: VEB Verlag für Bauwesen, 1989, 64.
6. Hays, K. Michael, *Modernism and the Posthumanist Subject. The Architecture of Hannes Meyer and Ludwig Hilberseimer*, Cambridge (MA): MIT Press, 1995, 113.
7. Oswalt, Philipp, "Einleitung." In Oswalt, P. (Hg.), *Hannes Meyers neue Bauhauslehre. Von Dessau bis Mexiko*, Basel: Birkhäuser, 2019, 11.
8. Meyer, Hannes, "Die Neue Welt," *Das Werk* 13 (1926) 7: 205–224. The translation in Claude Schnaidt, *Hannes Meyer. Buildings, Projects and Writings*, Teufen: Niggli 1965: 91–95, has been modified for a more direct translation.
9. Wittwer 1985, 72.
10. ABC (1925) 6: 3.
11. Cp. Wittwer, Hans-Jakob, *Hans Wittwer,* Zurich: gta 1985, 26 and 14. Wittwer's competition report seems to be lost; no calculations could be found in the gta Archives. Karl Moser, Wittwer's former professor and competition jury member speculated after the competition, in a letter to Wittwer from March 1926, that "engaging in light theory" might have "blocked you a little." Quote in Wittwer 1985, 14. See also Winkler 1989, 61.
12. Cp. Wittwer 1985, 14. Voellmy explained the acoustical concept of Meyer/ Wittwer's Palace of the League of Nations competition entry in *Das Werk* 14 (1927) 7: 226.
13. Locher-Ernst, Louis, Ernst Trost, P. Buchner, "Nachruf: Erwin Voellmy-Wittwer," *Elemente der Mathematik* 6 (1951) 2: 25-26.
14. *bauhaus* 2 (1928) 2/3: 32. No teaching notes could be found in the gta Archives and the Bauhaus Dessau Foundation Archive. See also Hoffmann, Hubert, "Erinnerungen eines Architekturstudenten," in Oswalt 2019, 116-117.
15. Baur, Hermann, "Zum Wettbewerb für die Petersschule Basel," *Schweizerische Bauzeitung* 89 (1927) 15: 196–198. Architect Hans Mähly won the competition. Daylighting was an important point of discussion in the competition. In the *Schweizerische Bauzeitung*, Baur complained that all awarded projects had "great disadvantages," such as "a shaded courtyard or a larger number of unfavorably lit class rooms."
16. *bauhaus* 2 (1927): 5.
17. From a scientific point of view, Meyer and Wittwer did not present evidence that the site was too shady, thus grounding the entire argument on a non-measured impression. On the other hand, the narrow building site was critiqued also by contemporaries, such as Baur 1927.
18. Higbie, Henry Harold, "Prediction of Daylight from Vertical Windows," *Transactions of the Illuminating Engineering Society* 20, (May) 1925: 433-476. Higbie, Henry Harold and Levin, A., "Prediction of Daylight from Sloping Windows," *IES Transactions*, 21 (1926): 273-373.
19. Commission of the European Communities, *Daylighting in Architecture. A European Reference Book*, edited by N. Baker, A. Fanchiotti and K. Steemers. London: Earthscan, 1993, F.1.
20. Higbie/Levin 1926: 305 and 274.
21. Higbie 1925: 461. Higbie/Levin 1926: 276.
22. Cp. Higbie/Levin 1926: 274-275.
23. Consider Higbie/Levin 1926, 277: "All angles in this formula must be expressed in radian measure."
24. Cp. CIE, *Geschichte der Internationalen Beleuchtungskommission,* Paris 1963. Today's unit is 1 candela, which equals to 1 lumen/steradian.
25. The following quote from Alexander Pelham Trotter in *Illumination. Its Distribution and Measurement,* London: Macmillan 1911, 17, provides a flavor of this discussion: "The unit of illumination produced by a bougie-décimale at a metre has been called a bougie-metre, and the name "lux" was […] applied to this unit. […] So long as the Hefner unit remains, the confusion between the metre-candle and the metre-Hefner makes the use of the term "lux" ambiguous."
26. Cp. Darch, John, "Illumination as a Study for Architects," *Journal of the Society of Architects*, Feb. 1912, 5, 52, 129-150, esp. p.132: "Sunlight often reaches 8,000 ft. candles, and we find that a diffused daylight of 2,000 ft. candles is both comfortable and healthy, while from that to 100 ft. candles is our daily experience. Such intensities are far in excess of anything we ever get in artificial lighting, for a general illumination of 5ft. candles would be considered quite brilliant."
27. The division sign "/" is hardly visible in the bauhaus publication, but it exists in the original drawing.
28. Waldram, P.J. "The Measurement of Illumination; Daylight & Artificial. With special reference to Ancient Light Disputes." (British) *Journal of the Society of Architects* 3 (1910) 28: 132. Cp. the *Handbuch der Hygiene,* 1896, which refers to proponents of top-lighting.
29. Higbie 1925, 439.
30. Wittwer 1985, 67.
31. Waldram 1910: 131.
32. Brown, Wendell S., "Bringing Daylight Through the Walls," *The American Architect and Architectural Review,* Oct 8, 1924: 348.
33. Brown 1924: 345.
34. *Journal of the Society of Architects* 2 (1908) 13: 25–26.