Assessing the impact of outside view on learning: a close look to EN 17037 ‘view out’ practices through the analysis of 220 classrooms

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Abstract. The purpose of design standards and guidelines is to ensure occupant safety and aid in occupant well-being and satisfaction. Educational buildings such as schools should extend this aim, by also promoting student learning, something that has triggered literature in the past suggesting significant correlation between learning performance and the indoor environment. EN 17037 “Daylight for Buildings” is a recently approved European standard that seeks to assess and ensure successful daylit spaces, including sections on protection against glare, exposure to sunlight, and view out. EN 17037 includes three ways of assessing view out in buildings including, Horizontal sight angle, Outside distance of the view, and Number of view layers outside of windows, a combination that potentially makes it an efficient way to describe such a complex concept. This paper will use a large data set of 220 K-12 classrooms in the Midwest region of the United States in order to evaluate whether any of these three levels of assessing view, or combinations of them can show potential effects on student achievement. The Number of view layers showed a significant positive effect on reading achievement. However, none of the metrics were found to be significant with respect to math achievement. These results aim to identify the next steps of a future controlled study towards a better quantifiable understanding of outside view perception, while also triggering a conversation about the main factors connected to outside view that should be considered towards an indoor environment that promotes learning and productivity.

1. Introduction
Design standards and guidelines exist to ensure occupant safety and enhance well-being and satisfaction. Educational buildings should also aid in student learning and development. Past literature has indicated that significant correlation exists between the indoor environment and learning (e.g. Durán-Narucki, 2008; Heschong & Mahone, 2003; Hines, 1996). EN 17037 “Daylight for Buildings” is a recently approved European standard that seeks to assess and ensure successful daylit spaces, including sections on protection against glare, exposure to sunlight, and view out. View out is a concept that has had minimum study over the years compared to topics such as glare, lighting and daylighting. Past literature has been examining view in different ways; focusing on settings with and without windows and primarily their psychological and health effects (e.g. Butler & Biner 1989; Collins 1975; Finnegan &
Solomon 1981), braking view out into quantity and quality aspects (how much view is available and whether the view is natural or urban), focusing on psychological and health effects (e.g. Bouzekri et al. 1991; Ulrich, 1983; Tenessen & Cimprich, 1995). All these studies showed that people were happier and healthier with the presence of a view. Several other aspects of view assessment have been used more recently, including view quality, (a five-point rating accessed to each viewing location by a small independent group of raters) by Aries, et al. 2010, interest of view (Tuaycharoen & Tregenza 2007) or human activity (Heschong & Mahone 2003). Most of the above studies were evaluating view in terms of human satisfaction. However, when the scope of research is the analysis of educational facilities, then student performance and learning become the priorities. These are most often assessed through standardized test scores with a typical emphasis on math and language arts (Durán-Narucki, 2008; Heschong & Mahone, 2003; Hines, 1996).

EN 17037 combines many of these ideas about view out into to three distinct view metrics: Horizontal sight angle, Outside distance of view and Number of view layers. Horizontal sight angle focuses on the amount of outside view available to a space by defining the width of a person’s view out of a space. The minimum recommended level of view width ranges from 14° to less than 28°, the medium recommendation from 28° to less than 54°, and the high recommendation is greater than or equal to 54°. The reference point used for this calculation should be the farthest point of utilized space, therefore, for this evaluation, the farthest point of the student seating area to the window will be used. Outside distance of view helps to define the amount of visual information available outside. More specifically, it is defined in EN17037 as the “distance from the inner surface of view opening to opposite major obstructions located in front of the opening”. (Technical Committee CEN/TC 169, 2018) An obstruction is defined as “anything outside a building which prevents the direct view of part of the sky”. (Technical Committee CEN/TC 169, 2018) The minimum recommended level of view distance is 6.0 m to less than 20 m, the medium recommendation from 20.0 m to less than 50 m, and the high recommendation is greater than or equal to 50.0 m. The View Layers metric focuses on the quality of the view out, and is defined by EN 17037 based on the assumption that there are “three distinct layers comprising a view: a layer of sky, a layer of landscape and a layer of ground” (Technical Committee CEN/TC 169, 2018). The minimum recommended level of view layers is at least a view of the landscape layer, the medium recommendation is at least the landscape layer plus sky or ground in the same view opening, while the high recommendation requires all three layers visible from the same view opening. The standard considers as landscape any urban and/or natural objects in view, or the horizon line. The horizon line is included in the landscape layer to ensure that landscape is included even if the view out only has the ground and sky out to the horizon, without including the landscape.

This paper takes all three view metrics and evaluates them using a classroom data set containing 220 K-12 classrooms. The dataset comes from a four research grant funded by the US Environmental Protection Agency (EPA) (2014-2019), looking in to the environmental effects of classrooms on student achievement and included K-12 classrooms spread across the Midwest region of the United States. The main factors investigated in the wider project included thermal comfort, indoor air quality, acoustics, lighting (electric and daylighting) and view environmental conditions. The factors that will be used in this study include math achievement, reading achievement, free/reduced lunch recipients, gifted students, special education students and the three view metrics from EN 17037.

2. Methodology
2.1. Participants
This study included 220 k-12 school classrooms in the Midwest region of the United States spread across five school districts, each one represented by one data point. This approach was followed to address privacy concerns in populations of minors. The breakdown of classrooms for elementary, middle, and high school classrooms consisted of 144 classrooms in 31 elementary schools, 32 classrooms in 5 middle school schools, 44 classrooms in 5 high school schools. Approximately 8300 students were involved in this study. Elementary schools had 3rd and 5th grade classrooms selected. Middle schools had 8th grade English and math classrooms selected. High schools had 11th grade English and math selected.
2.2. Measurement Procedures and Data Acquisition
All measurements were conducted over a two-year period starting in September 2015 and ending in May 2017, 110 classrooms in the first year and 110 in the second. Each classroom was measured during the fall, winter and spring. In the fall, geometry measurements were taken for each classroom to map out the locations of every door, window and wall. Photos of the interior and the outside views of the classroom were taken during the fall, winter, and spring. The photos of the classrooms were taken in the corners of the room in a clockwise direction to ensure the entire space was captured. In the spring, the student seating area was identified in each classroom by measuring the distance from each corner and the center of the seating area to the wall and nearest window. Pictures were taken at the four corners and center of the student seating area at student seating height. Figure 1a shows an example of these points.

Student achievement data was acquired as classroom aggregate data from the Nebraska state assessment and the Iowa state assessment. The student achievement data was provided as percentile rank in math and reading scores. Since middle school and high school classrooms switch rooms for math and English classes, only math scores were used for math classrooms for the cases of middle and high school and only English classrooms with reading scores. In order to control for variations in socioeconomic status and learning ability, each school district provided demographic information for free & reduced lunch recipients, gifted learners, and special education students.

2.3. View Metrics Variables
Although **Horizontal sight angle** uses categories to define its variables, it is arranged in a linear manner and can be evaluated linearly. For that reason, in this study, a value below $14^\circ$ would receive a value of 0, greater than or equal to $14^\circ$ would be a value of 1, greater than or equal $28^\circ$ would be a value of 2 and value greater than $54^\circ$ would receive a value of 3. The **Outside Distance of the View** is measured from the outside of the view opening to the nearest obstruction. In that sense, **Outside distance of view** was also evaluated in the same linear manner as **Horizontal sight angle**. **Number of view layers** seen is to be calculated from at least 75% of utilized area. Number of layers was evaluated using the photos taken from the farthest corner student seating location. View layers were also evaluated linearly. Figure 1a visualizes the **Horizontal sight angle** and Figure 1b the other two factors.

![Figure 1: (a) Example Classroom Floor Plan, (b) Example Section Cut for View Metrics](image)

3. Results
3.1. Descriptive Statistics and Regression Analysis
IBM SPSS Statistics 24 was used to conduct both multivariate linear regression models preformed in this study. The descriptive statistics for the achievement, demographic, and view metrics used in this analysis are shown in Table 1.
Table 1. Descriptive Statistics

| Variables                      | N   | Mean  | Std. dev. | Min  | Max  |
|-------------------------------|-----|-------|-----------|------|------|
| Math Achievement              | 178 | 56.74 | 14.76     | 18.33| 95.98|
| Reading Achievement           | 181 | 55.59 | 14.08     | 5.00 | 87.30|
| % Free Lunch                  | 218 | 37.79 | 29.88     | .00  | 100.00|
| % Special Education           | 218 | 14.44 | 12.03     | .00  | 100.00|
| % Gifted                      | 218 | 13.49 | 13.73     | .00  | 76.09|
| Horizontal Sight Angle        | 215 | 1.50  | 1.234     | 0    | 3    |
| Outside Distance of View      | 215 | 1.59  | 1.176     | 0    | 3    |
| View Layers                   | 215 | 1.99  | 1.162     | 0    | 3    |

For the regression analysis, the multiple regression rules detailed by Cohen (2003) were followed. The SPSS data file used the raw scores for achievement and view metrics but the demographic variables were centered to reflect the average classroom. Centered demographic variables allowed for easier interpretations of the coefficients of the independent variables. Hierarchical multiple regression was performed in order to separate the contribution of the demographic variables from the view metric variables. For the multivariate regression, all analyses were done using listwise deletion for all variables to be present for each classroom to be analyzed. All variables were tested for normality with histograms and skew/kurtosis measures. The percentage of special education students showed problematic skew and kurtosis as values exceeded 3.0 and 8.0 respectively according to Kline (1997). However, these were expected for this variable as the percentage of the population with disabilities is relatively low, resulting to the normal distribution being cut-off by the left boundary condition. Multicollinearity was checked through a correlation analysis, showing that distance to obstruction and view layers had a high correlation (r = .732) which could be problematic. Since the correlation is considered to be potentially problematic, SPSS collinearity diagnostics were run, using condition number test. The condition number values for the math and reading analysis were 7.899 and 7.656 respectively, both below the rule of thumb threshold of 30 according to Cohen (2003). This confirmed that collinearity between independent variables was not problematic.

3.2 Regression analysis of Reading on Demographics and View Metrics.
The hierarchical multivariate regression was performed between reading achievement and percentage of free and reduced lunch students, percentage of special education students, percentage of gifted students, Horizontal sight angle, distance to obstruction, and view layers. The regression contained two models: (i) model one to capture the regression of reading achievement on just the demographic variables and (ii) model two, reflecting the regression of reading achievement on the demographic variables and view metrics. The model one analysis of reading achievement accounted for 48.6% of the variance in reading achievement (R² = .486). Model two analysis of reading achievement showed an increase in explained variance in reading achievement to 50.5% (R² = .505). The three view metrics improved the overall model by 1.9%. This model improvement suggests that the view metrics do play a role in reading achievement. However, the effect is marginal compared to the demographic information. Looking at each view metric individually view layers is a positive significant predictor (p = .016) of reading achievement. This relationship implies that the increase of visual information from the outside environment increases reading achievement. Table 2 shows results of the model two analysis.
Table 2. Multiple Regression of Reading on Demographics and View Metrics

| Model Two | B    | SE   | t     | β    | F    | R²   | 95% CI          |
|-----------|------|------|-------|------|------|------|----------------|
| Intercept | 52.96| 1.74 | 30.38**| 28.78**| .505 | [49.46, 56.33]|
| % Free Lunch | -0.14| 0.03 | -4.85**| -0.29 | [-0.19, -0.08]|
| % Special Education | -0.33| 0.08 | -4.35***| -0.25 | [-0.48, -0.18]|
| % Gifted | 0.52 | 0.06 | 8.20**| 0.47 | [0.40, 0.65]|
| Horizontal Sight Angle | -0.55| 0.77 | -0.71 | -0.05 | [-2.08, 0.98]|
| Outside Distance of View | -1.00| 0.99 | -1.01 | -0.08 | [-2.95, 0.96]|
| View Layers | 2.71 | 1.12 | 2.43*| 0.20 | [0.51, 4.91]|

Note. N = 176. *p < .05. **p < .01.

3.3 Regression analysis of Math on Demographics and View Metrics.
Similarly with the analysis of reading, the hierarchical multivariate regression was performed between math achievement and percentage of free and reduced lunch students, percentage of special education students, percentage of gifted students, Horizontal sight angle, distance to obstruction, and view layers. The two models of the regression were structured equivalently with the ones for the reading achievements, with and without the view metrics. Model one showed that the demographic variables without the view metrics accounted for 60.0 % of the variance in math achievement (R² = .600). Model two with view metrics included showed an increase in explained variance in math achievement to 61.1% (R² = .611). Although this 1.1% increase is a noticeable improvement in the model, it is not high enough to produce an effect, something that is reflected by the fact that none of the view metrics proves to be significant. One interesting note from this analysis is that Horizontal sight angle is close to being significant (p=.077) in the negative direction. If this was significant, the analysis would have indicated that increasing the width of the windows in a space could decrease math performance. This would be compatible to a finding of Boubekri et al. (1991), where the treatment was manipulating window size to increase sunlight penetration on relaxation.

4. Discussion and Continuation of this Work
This study presents the preliminary results from an observational investigation of 220 K-12 classrooms across the Midwestern region of the United States that, among other objectives, aimed to investigate the impact of the factors addressing view out in EN 17037 on student learning. The results concluded that only the view layers metric is a significant predictor of reading achievement. However, this effect corroborates to some extent many concepts explored in the literature regarding view quality (Aries et al. 2010), view interest (Tuaycharoen & Tregenza 2007) or human activity (Heschong & Mahone 2003). Outside distance of view and Horizontal sight angle were not found to have a significant impact on student achievement, however this can be related to the limitations of this project, described as follows: (i) The results of this paper come from an observational study of classrooms with no way to experimentally control for confounding variables. This was primarily a result of the need to not interfere with the everyday activities of the classes, but also related to the increased privacy concerns regarding experiments with young students of K-12 schools. (ii) The view metrics themselves introduce some limitations; the Outside distance of view is inherently related to view layers, as the further the distance to a major obstruction, the larger the vertical view height, potentially leading to more layers within the view. That relationship leads to the metric of Outside distance of view sharing much of the same information as view layers. At the same time, ‘view layers’ provides more information about the visual environment, making the ‘Outside distance of view’ obsolete. The Horizontal sight angle is potentially affected by the negative aspects of increased window surface areas, such as having excessive sunlight penetration, also shown in Boubekri et al., (1991). The sole difference is that Horizontal sight angle appears to be linear based on a scatterplot of Horizontal sight angle and achievement variables. where
Boubekri et al. found the relationship to be quadratic. Currently, more research is needed to better understand what may or may not be occurring regarding the variable of **Horizontal sight angle**; one approach to test for daylight effects would be the moderation of **Horizontal sight angle** with window orientation. If the south orientation has a significant negative effect but the north orientation has no effect or a significant positive effect, this would be an indicator that direct sun is playing a major role in the results.

The current work of the investigators includes designing a controlled experiment that will allow more detailed investigation of the impact of view in cognitive performance and activities related to education and learning. The results from this preliminary observational study will be used as a starting point to further look into the impact of view from a more causal perspective. The response variable that will be explored will be a combination of different aspects constituting cognitive performance, evaluated in short duration activities, and the experiment will take place in dynamic window settings to capture the impact of view while having control of the most dominant confounding factors. Part of this process will be also to shed light on gaze behaviour of the participants to better understand how windows are being within the space.

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