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Summary Report: Post-Occupancy Evaluation Surveys in K-12 Learning Environments

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WHAT SCHOOL BUILDINGS CAN TEACH US:

POST-OCCUPANCY EVALUATION SURVEYS IN K-12 LEARNING ENVIRONMENTS

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ABSTRACT

Using the CBE Indoor Environmental Quality Occupant survey, (POE) surveys were conducted in 61 school buildings across the country (roughly 1700 teachers and staff completed the survey), 11 of which were designated as “green” buildings (defined here as having either a LEED certification or an AIA Committee on the Environment Top Ten award). Detailed information about each building was collected, including occupancy demographics, size, age, and general information on HVAC systems. User satisfaction scores were compared to various design features in school environments, to investigate the nature of the relationship between school building design and teacher satisfaction with indoor environments. Students were not surveyed, due to difficulties in getting access to students, and the large age range of students in schools that were surveyed (K-12). However, teachers proved to be very thorough and representative respondents, often responding representatively for their students.

The primary objective of this research is to demonstrate the usefulness of occupant feedback mechanisms in school buildings, both for individual building feedback loops, but also for school districts and the industry as a whole. The study aims to show that POEs can produce a variety of interesting, relevant and targeted results with minimal effort and inconvenience to staff and students. Finally, the study aims to identify some trends in school buildings that may have a positive or negative impact on teacher satisfaction. This can ultimately help designers to better understand the implications of certain school design features, and support the argument that school facilities impact overall school quality.
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I PROJECT BACKGROUND AND INTRODUCTION

This project was conducted primarily for a Masters Thesis in Architecture, concentrating in Building Science. One of the primary focuses of the research project was to develop a core IEQ satisfaction survey for classroom environments that followed the methodology of the more general office environment survey used by CBE to date, with a particular interest towards high-performance design features that are becoming more pervasive in K-12 design today. Although there was interest in also looking at energy consumption data (through Energy Use Intensity comparisons) to look at patterns in energy consumption with patterns in occupant satisfaction, this was not possible to collect for all buildings at the time. Many other school buildings have also populated the CBE database since the synthesis of this data set in 2009, and further research may be fruitful as a larger population of teachers and school buildings is compiled.

1.1 RESEARCH BACKGROUND

In considering the built environment in America today, it is tempting to divide the landscape primarily into two building types- commercial and residential buildings. Yet, a quarter of the population spends most of their day in a third type of building- the school building. A recent study by the Building Educational Success Together (BEST) collaborative estimates that from 1995-2004, public school districts across the US spent $504 billion in school construction (capital projects), making this sector, by some estimations, the largest commercial building sector by cost in the country today (Filardo et al., 2006).

Despite this significant capital investment, little is known about how school buildings perform in practice. As Stewart Brand noted in How Buildings Learn, schools are among our most permanent buildings (1995). And so, when new design techniques and concepts enter the school design world, they are typically measured and monitored carefully; every decision made in a school is one that may be lived with by four, five or more future generations of students.

This study follows in this tradition of assessment, to look specifically at how occupants perceive a set of building design strategies. This work also benefits greatly from similar studies of schools conducted in the UK by the Usable Buildings Trust, and past studies at the CBE that have analyzed the results of other sets of buildings in the CBE database (Abbaszadeh, 2006; Bordass et al., 1999; Huizenga et al., 2006). It also provides some research to challenge notions of ideal classroom environments, by showing the complexity and diversity of preferences that teachers have for their indoor environments.

This research also may be useful to those who study the impact that school facilities have on student achievement, though student performance variables were not analyzed in this particular study. The dependent variable assessed here is teacher satisfaction, which some have shown to be positively correlated with teacher retention, and hopefully with student performance. Rooted more specifically in building science, this study looks carefully at building design features, rather than learning outcomes or other educational issues arising from building condition, on which there is a broad and thoughtful body of scholarship.

Finally, this study responds to recent discussions in the green building industry, regarding the impacts that green buildings have on their occupants. Various studies and media articles have reported sizable improvements in occupant well-being, productivity, etc, in green buildings, but few controlled studies have constructed rigorous comparisons that illustrate this effect convincingly. This study provides a modest contribution to this debate, through an analysis of 11 “green” buildings with 10 contemporary “non-green” buildings, which is a major sub-set of the findings below.
2 METHODS

Post-Occupancy Evaluation (POE) Surveys were conducted in 61 school buildings across the country (roughly 1700 teachers and staff completed the survey), 11 of which were designated as “green” buildings (defined here as having either a LEED certification or an AIA Committee on the Environment Top Ten award). Detailed information about each building was collected, including occupancy demographics, size, age, and general information on HVAC systems. User satisfaction scores were compared to various design features in school environments, to investigate the nature of the relationship between school building design and teacher satisfaction with indoor environments. Students were not surveyed, due to difficulties in getting access to students, and the large age range of students in schools that were surveyed (K-12). However, teachers proved to be very thorough and representative respondents, often responding representatively for their students.

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2.1 CBE BUILDING OCCUPANT SURVEY

Since 2003, the Center for the Built Environment (CBE) at the University of California at Berkeley has administered occupant surveys in over 500 buildings through its Indoor Environmental Quality Occupant Survey tool. The CBE survey was designed to assist building industry professionals in obtaining useful feedback data to manage facilities and for other uses in the building industry such as gaining insight into occupant perception and comfort in buildings. It measures occupant satisfaction with aspects of the indoor environmental quality (IEQ) in their workspaces, and has been primarily used in office environments. From a participant’s point of view, the survey is anonymous and voluntary; building occupants are invited to take the survey by their building managers, owners or supervisors, but are not obliged to do so. Participants receive the invitation via an email, with a link to the online survey, and basic information about the survey (notice that the survey is confidential, that it will take roughly 15 minutes, etc). Typically, the CBE survey period lasts for 2 weeks, although it can be extended if the response rate is low. For the purposes of this thesis, school contacts were challenged to get a response rate of at least 50%, and so in some cases the survey period was extended in an effort to achieve this level of participation. The CBE recommends that building contacts send reminders to occupants when they have one week left to complete the survey, and again one day from the deadline.

The CBE survey is typically split into the following ten categories of questions: Background (demographic questions), Workplace Description, Office Layout, Office Furnishings, Air Quality, Acoustics, Lighting, Thermal Comfort, Cleanliness and Maintenance, and General Satisfaction. Along with collecting basic information about each respondent’s access to various types of controls (like light switches or thermostats), the survey collects information about the approximate location of occupants (asking for specific locations would compromise confidentiality). Within each of the survey’s categories, a series of satisfaction questions are asked, on a 7-point Likert scale (see Figure 1 for an example), which is generally labeled on a scale from “Very Dissatisfied” to “Very Satisfied”.
In an effort to learn more detail about the sources of dissatisfaction in indoor environments, there are also “branching” questions in the survey. When a respondent answers with a negative score (below “Neutral”) on general satisfaction questions like the one in Figure 3.1.a, they are asked for the reason(s) why they are dissatisfied. This allows the CBE survey to collect more specific information without extending the length of the survey as significantly.

### 2.2 K-12 SCHOOL ENVIRONMENTS AND POE SURVEYS

For the purposes of this study, the CBE survey was adapted to school environments in three key ways:

1. Patterns of occupancy: many full-time staff in school buildings are teachers, who a) might not occupy a single desk area for a full day, but rather might move from classroom to classroom, and b) certainly might supervise spaces larger than an individual workstation or desk.

2. Use of Controls: since classrooms tend to be more controllable than office spaces by nature of their use, more questions were asked regarding the frequency of use for various thermal comfort controls such as thermostats and operable windows.

3. Administrative vs. Educational staff: the survey gathered satisfaction scores separately for the two basic types of staff in the building: educational staff (teachers and aides) and administrative staff.

In the context of educational commissioning and other types of surveying techniques used for school buildings, it should be noted that the CBE survey remains a tool for building industry professionals. As such it has focused less on teaching effectiveness, and on the aspects of environments that are not under the control of building professionals (such as information technology, which tends to be excluded from the scope of this industry’s role in schools). In addition, this study does not actively consider the equity and financial factors that affect a school’s facilities and resources to maintain facilities. Future work will likely extend the survey to address other educational and policy-related aspects of the built environment of schools, for the sake of better understanding the full scope of high-performance learning environments. But for this study, the surveys remained in the scope of the existing CBE survey framework.

In general, the CBE tool has proved a very useful tool for architects, building managers, portfolio owners, engineers, and others who seek to gain a better understanding of the buildings they engage. The survey has gained popularity as it offers a convenient strategy for achieving points in the LEED rating systems, as mentioned above. It continues to expand its reach in new building markets, in new countries and languages, and in the variety of building systems it can address.

### 3 FINDINGS

The researchers were fortunate to have the help of many organizations (the Council for Educational Facility Planners International- CEFPI, the US Green Building Council, the AIA Committee on Education, and others) to recruit a set of 61 school buildings for the study. Participation in the study
was free for all parties, as long as they could commit to obtaining a 50% response rate for all school buildings, and could complete the necessary sign-up form (which included building characteristics information). All schools in the study were occupied fully during the ‘07-‘08 school year, and surveys were conducted throughout the ‘08-‘09 school year.

Figure 2: School Building Age Distribution: Study sample vs. US stock

The sample group of buildings represents all of the major DOE climate zones, including buildings in more humid climates along with dry ones. The group includes 41 elementary schools (which tend to be smaller and more numerous), 10 middle schools and 10 high schools. The size of the buildings ranges from 21,000 gross square feet (a small elementary school) to 475,000 gross square feet (a large high school). The buildings range in age from an example built in 1902 to schools just completed in time for the 2007-08 school year (since all schools had to be fully occupied during that school year to be eligible for this study). The range of building ages is roughly representative of the US school building stock, as is shown in figure 2, except that the study sample has more new buildings built in the past decade.

A number of reassuring findings emerged from this collection of occupant responses, which support many trends and theories in school design today. Some of the more notable findings will be presented in this paper, however more details are available in a Master’s Thesis.

3.1 GENERAL SATISFACTION

In general, occupants were more satisfied with newer buildings than older ones, as shown in Figure 3, which shows average general satisfaction scores for each building compared to the date of construction. However, it should be noted that this is merely a trend, likely influenced at least in part by the fact that newer schools generally have fewer broken systems, and tend to look cleaner and more functional. This does not necessarily indicate that they are better designed schools. The oldest school building in the study, a small private school building in Pennsylvania originally built in 1902, had some of the highest scores in the study, across the board. In addition, a large urban
public high school in Montana built in 1953 also reported some of the highest satisfaction scores in the study.

Figure 3: General Satisfaction Scores by Era

Figure 3 also shows the distribution of certified green schools and other “conventional” newer schools (all of which were built since 1999), showing that the certified green schools generally scored higher on general satisfaction with the building than conventionally built school buildings.

Figure 4 shows that the certified green schools outperform their contemporaries in a number of categories, most notably in thermal comfort, air quality, lighting and in general satisfaction. These trends will be discussed more in detail in topic-specific sections to follow below, with the exception of general satisfaction. As Figure 4 shows, the schools built to meet a high performance standard tended to have higher overall satisfaction than their new counterparts, and overall higher satisfaction than other buildings.
3.2 LIGHTING

Some of the most striking findings in the study were found in the category of lighting satisfaction, where noticeable patterns emerged quickly between older buildings, those without windows, and certified green schools. One important line of inquiry for this study was to investigate the occupants’ perceptions of classrooms with and without windows.

Figure 5 Date of construction vs. windows in classrooms

Windowless classrooms have long been a subject of research, with many recent research studies showing that they have a variety of negative impacts on occupants well-being, and perhaps even test scores. However, research in the 1970s argued to the contrary, to the effect that many school buildings were built without windows. Researchers then believed that it may prove less distracting
for students. Indeed, this trend lasted throughout the 1970s, but then was abandoned over time. The sample set of buildings for this study mirrors this trend well, as can be seen in Figure 5, which shows all buildings in the study, pulling out the percentage of classrooms of survey respondents without windows. Perhaps unsurprisingly, the survey found that teachers in these windowless schools had very low lighting satisfaction scores overall, as is shown in Figure 6. What is surprising is that they underperform so noticeably from their peers, representing 7 of the 10 lowest performing schools in the study.

![Figure 6 Lighting Satisfaction in 1970's schools vs. others](image)

Ample comments from occupants on this issue further illustrate the dynamics of these situations. One teacher noted, amusingly, “I do the in-school suspensions, detentions & time-outs. In my opinion, no windows, no clock and a smaller classroom environment enhances the student's feeling that 'Your next step could be the truancy center.'” Another reported the difficulties of working with particularly challenging groups, noting, “Teaching emotionally disturbed youth in a windowless, stagnant environment makes things even more difficult.” On the other extreme, one occupant in a new certified green school noted that the positive impact of natural light was striking, saying, “I am amazed at how much impact the natural light and indoor/outdoor space has on the students and my own overall wellbeing.”

Teachers in classrooms with at least one window were more satisfied with their lighting than teachers without any windows. It should be noted that most teachers reported having at least one window- 1368 out of 1694 teachers reported having at least one window in their primary classroom. The correlation between having a window and visual comfort satisfaction was shown to have a small positive correlation, with a Pearson correlation coefficient of $r = 0.2$, with a 99% statistical certainty.

However, access to natural light through windows is not always a good thing. One occupant notes, “[w]e have tons of natural light which is wonderful, but it interferes with the use of the ActivBoard.” Another discusses the importance of controls for the varying activities that occur in classrooms, noting, “If our lighting could be in the classroom with 3 switches, we would be able to control and dim 1 row of lights thus saving electricity and controlling the brightness of the room.”
In addition, by investigating the results of the new and certified green school surveys in more depth, we see that there are some issues in certified green schools, especially for those schools scoring lower than the average school. One occupant notes, “My program requires and relies on the use of slides, videos and/or projection of visual material. These technical supports enhance my teaching and curriculum. While the amount of natural light entering my workspace is fantastic - I am unable to control this sufficiently. The shading system that was installed is inadequate and very un-user friendly. Some ideas, while 'cool', do not pan out in practice.”

**Figure 7: Lighting Satisfaction in certified green vs. conventional new vs. pre-1999 schools**

Similarly, Figure 8 shows the reported sources of dissatisfaction in the certified green schools compared to their contemporaries built since 1999, showing that the certified green schools seem to have more complaints about brightness, reflections on computer screens, and other issues associated with daylighting. Meanwhile, the biggest complaint in the new schools without a green certification is the lack of daylighting, a finding that again reinforces the importance of this feature, and the fact that teachers notice the absence of daylighting and are dissatisfied with it.
3.3 THERMAL COMFORT

Thermal comfort has been a major consideration in many POE studies, and this one is no exception. Since thermal satisfaction can be highly variable and impacted by many different conditions, it is especially useful to conduct occupant surveys to determine whether trends in thermal comfort are present in buildings. In order to better understand the situations of many school building occupants, it is helpful to consider the differences between school occupants and office occupants, in terms of thermal conditions and access to controls. In school buildings, which are mostly classrooms, employees (teachers, often) typically have more control over their thermal environment than an office worker, as shown in Figure 9.

Figure 8: Reasons for Lighting Dissatisfaction: certified green vs. conventional new buildings
Thus, in schools, thermal comfort is often very connected to the level of control that occupants have, especially given that activities in classrooms range over the course of a day, occupants are likely to be coming inside and outside more frequently, and temperature is one aspect that teachers may use to help set the mood of the classroom. The survey findings supported this notion, showing that teachers with thermal controls (thermostats, especially), had higher levels of thermal comfort satisfaction than those without much control.

High-performance school certification programs emphasize a number of design strategies that have an impact on thermal comfort. Energy-saving strategies often call for less occupant control (and more centralized control) of energy-consuming equipment like heating and cooling systems. Daylighting strategies may affect thermal comfort either through increased solar gains in perimeter classrooms, or heat loss associated with daylight-admitting windows. Thermal comfort control is also encouraged in these certification programs, so it was interesting to see the results, which do not show a clear improvement in the thermal comfort reported by respondents in certified green schools compared to other schools (including new ones), as is shown in Figure 10.
Some certified green schools are quite high-performing, while others are less so. In reviewing the specific comments and complaints lodged by individuals in these low-performing school buildings, a few general insights were unearthed. As one occupant notes, “for a building that is supposed to be passively comfortable, and easily controlled, it is odd that it often feels as if an air conditioner is on full blast.” Also, certified green school occupants report more frequently that they are dissatisfied due to incoming sun, which may be related to daylighting-related features that often accompany certified green classroom designs (see comments reported in the lighting section for information about overly daylit spaces in high performance schools).

Operable windows were initially a major area of focus for this study, in the hopes that some clear correlations between various satisfaction scores and access to operable windows would be found. In fact, basic correlation tests showed that occupants with operable windows are actually less satisfied, on average, with their thermal comfort than those who do not have access to an operable window. The result was initially surprising, because current design trends have encouraged operable windows as a means towards greater thermal comfort, as well as energy savings through natural ventilation techniques. It is also surprising given that this trend is not present in the office buildings that the CBE has surveyed.

Upon further investigation of comments from respondents regarding why they were dissatisfied with their windows, the story became clearer. In essence, many of the windows in the classrooms studied were older, having been installed in the 1950s, 60s or 70s. They are often single-pane windows with parts that are breaking or broken. One occupant notes this situation in depth, saying, “[t]hese windows are sad and pathetic. It is incomprehensible how we can claim to be concerned about energy use in our district (turn off the lights, the computer, turn down the heat etc.) but we can’t change out one of the biggest energy loss components in our building. When the wind blows, dirt blows in through the gaps in the windows onto the student work areas - visual proof as to how poorly these things seal.” This serves as a good reminder for designers today, that operable windows do require more long-term maintenance, and efforts to install sturdy assemblies with screens and convenient handles will be appreciated in the long run. Most of the newer buildings in
this study have operable windows, so there is no conclusive evidence to support operable window designs with the available data.

### 3.4 AIR QUALITY

In examining potential correlations between satisfaction scores and physical building characteristics, one of the strongest correlations was found, a correlation of $r=0.45$, between mean satisfaction scores with air quality and the year that the building was constructed. It should be noted that one of the oldest buildings in the dataset, a small school in Pennsylvania, still had very high satisfaction scores, which may be related to the fact that the building has been continuously renovated throughout its lifetime, and had recently undergone a renovation. Further research should be conducted to assess this relationship that incorporates considerations such as maintenance, renovation history, existing building features and set-up, and operations budgets. It should also be noted that not all new schools are performing well in air quality scores. This will be discussed in more depth in the following section, which breaks down the scores between the certified green schools and the other new schools.

![Air Quality Satisfaction vs. Date of construction](image)

Figure 11: Air Quality Satisfaction vs. Date of construction

One area in which high performance schools clearly outperformed their peers (both the new schools and all others) was the category of air quality. Occupants of high performance schools tended to report very high satisfaction scores, with a mean score in that group of buildings of 1.49 (see Figure 12 for these scores). This could be resulting from the tendency of these buildings to install low-VOC paints and finishes, thus reducing pollutants in the indoor environment especially in the initial months and years of occupancy. These buildings also tend to have more effective ventilation strategies and system control that can allow for increased ventilation. As one occupant noted, “I appreciate the CO2 fan, and I feel more alert because of this fresh air. The lights, the radiant heating, the windows, etc. all enhance the working and learning environment!”
During the survey process in one school district, representatives from that district informed me that they had 5 “open plan” schools they were particularly interested in assessing for acoustic performance. They had been considering a renovation of these schools, since they had been getting some complaints, and hoped that the survey process would shed some light whether the incidental complaints were representative of overall sentiments in these schools. These schools, all built in the 1970s, were designed with a concept popular at that time, that schools “without walls” would contribute to a better learning experience for students, by emphasizing collaborative learning and community-building. Thus, the interiors of the schools have no permanent walls, nor floor-to-ceiling partitions of any kind. In addition, district officials and the occupants noted that these “classrooms” (which are essentially just areas that are visually screened by low flexible partitions) do not feature windows or controls for their thermal or lighting environments. Respondents were quite clear about their perspective on these school buildings. Figure 13 shows the average acoustic satisfaction scores for all schools, with the 5 open plan classrooms highlighted. All 5 schools scored in the bottom 10%. Comments on these schools described the acoustic dissatisfaction that occupants feel. One occupant noted, “because there are no "real" walls (only cardboard partitions) defining classroom space, sound travels easily from room to room. Additionally, there are no "halls" which is extremely distracting.” Another commented on the effects of the open layout more generally, noting, “An ‘open school’ was a bad idea with good intentions. Schools need windows, walls, and halls to operate at their optimal levels. Workspaces and classrooms need to be clearly defined by walls and doors.”
This instance not only illustrates a clear trend regarding occupant satisfaction in open plan classrooms (as compared to normative classrooms), but also provides a great example of the practicality of running occupant satisfaction surveys to prioritize and assess known issues. Representatives from this school district noted that following the survey, they were able to show their school board the results of this study, as evidence of the need to install permanent interior walls and better acoustical systems in a renovation of these schools. Without these quantified data, it was possible for administrators to believe that the open classrooms, while disliked by some, might be preferred by the silent majority.

4 CONCLUSION

Although POE surveys, such as the CBE’s Occupant Survey have become more common in office buildings, an equivalent tool had yet been developed to gather specific feedback for schools, especially in a manner that could be executed easily. This study involved the creation of a tool based on the CBE survey for K-12 school buildings. The ease of use of the BOS for schools allows for another significant accomplishment of this study, which was collecting occupant satisfaction data and building characteristics for an initial sample of school buildings across the country. The great strength of this work will be more fully realized as larger numbers of buildings are entered into the survey collection tool. As the set grows, the potential for analysis and trending grows, as has been seen in the larger CBE dataset for office buildings. For this initial set of 61 school buildings, some trends are noticeable and may be indicative of larger trends in the country.

As noted throughout this thesis, the findings of this study suggest trends that might be found in school buildings across the country. Many of the findings support previous research done on indoor environmental issues in schools, and illustrate a method that can be used to gather more specific information about how teachers and students are reacting to their school environments. This performance information can help to identify problems and solutions at several scales — for the individual school and its improvement needs, for districts as they prioritize renovations, and for the
larger school building industry as it evolves new strategies for providing better learning environments.

Many of the findings in this thesis support other research in helping to strengthen the connections between various design features in schools and teacher satisfaction and well-being. Most notably:

- Teachers prefer classrooms with natural daylight, especially when they can control the amount of daylight with blinds or shades. Certified green schools tend to execute designs that support this preference better (although there are exceptions), as evidenced by higher average levels of lighting satisfaction.

- Teachers prefer classrooms with thermal controls, such as a thermostat or operable window. Certified green schools do not necessarily respond more effectively to this preference.

- Teachers report higher satisfaction with the air quality in certified green schools than with the air quality in other schools, both old and new.

- Acoustic satisfaction in schools is generally higher than in offices, but problems do arise. In particular, open-plan classrooms receive low scores from occupants in acoustics.

- Operable windows, while theoretically desirable and potentially useful for low-energy cooling and ventilation, can have problems, especially in older schools. Where window assemblies are deteriorating, occupants are very dissatisfied with both the resultant discomfort and perceived energy inefficiency.

This thesis also raises newer questions about interactions between school facilities and occupant comfort, particularly in the areas of new and high-performance schools. Evidence from this study shows that new schools can have problems, particularly with thermal comfort, and that occupants can be helpful in identifying problems in the first few months and years of operation. This research also shows interesting trends related to the epochs of school building in the U.S., which questions the premise that older school buildings are less valued by occupants. Future research in this area would be valuable, to determine what eras of school building have produced buildings that are most effective today.
5 ACKNOWLEDGEMENTS

This work would not have been possible without the gracious permission of a group of school representatives across the country, who helped to ensure that each survey was conducted thoroughly and with care. In addition, the help of the organizations who spread the word about the opportunity to take the survey was invaluable, especially that of the Council for Educational Facility Planners International, the US Green Building Council, and the American Institute of Architects (Committee on Education).

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6 REFERENCES


