

Summary Of Daylighting In Schools: Reanalysis Report

Reanalysis Summary (product 2.2.5x)

TECHNICAL REPORT

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PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

This document is one of 33 technical attachments to the final report of a larger research effort called *Integrated Energy Systems: Productivity and Building Science Program* (Program) as part of the PIER Program funded by the California Energy Commission (Commission) and managed by the New Buildings Institute.

As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The *Integrated Energy Systems: Productivity and Building Science Program* research addressed six areas:

- Productivity and Interior Environments
- Integrated Design of Large Commercial HVAC Systems
- Integrated Design of Small Commercial HVAC Systems
- Integrated Design of Commercial Building Ceiling Systems
- Integrated Design of Residential Ducting & Air Flow Systems
- Outdoor Lighting Baseline Assessment

The Program's final report (Commission publication #P500-03-082) and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the *Integrated Energy Systems: Productivity and Building Science Program*. The final report and attachments are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This attachment, #A-4, provides supplemental information to the program's final report within the **Productivity and Interior Environments** research area. It includes the following report:

- **Summary of Daylighting in Schools: Reanalysis Report.** This report provides an overview of the Daylighting in Schools: Reanalysis Study findings. It does not include the technical and statistical details found in the full report.

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced these documents as part of a multi-project programmatic contract (#400-99-413). The Buildings Program includes new and existing buildings in both the residential and the non-residential sectors. The program seeks to decrease building energy use through research that will develop or improve energy efficient technologies, strategies, tools, and building performance evaluation methods.

For other reports produced within this contract or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. All reports, guidelines and attachments are also publicly available at www.newbuildings.org/pier.

ABSTRACT

The “Summary of Daylighting in Schools: Reanalysis Report” is part of the Productivity and Interior Environments project, one of six research elements within the *Integrated Energy Systems: Productivity and Building Science* Program. The Program was funded by the California Energy Commission’s Public Interest Energy Research (PIER) Program. This report provides an overview of the findings presented in the “Daylighting in Schools: Reanalysis Report.” It does not include the technical and statistical details found in the full report.

This study expands and validates previous research by Heschong Mahone Group that found a statistical correlation between the amount of daylight in elementary school classrooms and student performance. The reanalysis found that:

- Elementary school students in classrooms with the most daylight showed a 21% improvement in learning rates compared to students in classrooms with the least daylight.
- More experienced or more educated teachers were not significantly more likely to be assigned to classrooms with more daylighting.
- The daylighting effect does not vary by grade.
- Physical classroom characteristics (daylighting, operable windows, air conditioning, portable classrooms) do not have an effect on student absenteeism. This seems to contradict claims that have been made about the health effects of daylight or other environmental conditions, as reflected in absenteeism rates of building occupants.

These results, which are consistent with the original findings, affirm that daylight has a positive and highly significant association with improved student performance. These findings may have important implications for the design of schools and other buildings.

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Re-Analysis Summary

Daylighting in Schools, Additional Analysis

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Full Report available at: www.newbuildings.org/PIER



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SUMMARY

BACKGROUND

This summary report is a part of the Public Interest Energy Research (PIER) program administered by the California Energy Commission and managed by the New Buildings Institute. Lisa Heschong of Heschong Mahone Group (HMG) led the research; a technical advisory committee has reviewed and accepted the findings. This summary is as an overview of the findings and does not include the technical and statistical details found in the full report.

PREVIOUS STUDY LINKS DAYLIGHT TO STUDENT PERFORMANCE

This reanalysis builds on previous research conducted by HMG and funded by Pacific Gas and Electric Company in 1999. That study found a compelling statistical correlation between the amount of daylight in elementary school classrooms and the performance of students on standardized math and reading tests.¹ These findings, which potentially have very important implications for the design of schools and other buildings where people live, work and play, generated significant attention nationally and internationally.

In the 1999 study, HMG analyzed test score records for more than 21,000 students in three school districts in San Juan Capistrano, California; Seattle, Washington; and Fort Collins, Colorado. The Capistrano study found that **students with the most daylighting in their classrooms progressed 20% faster on math tests and 26% faster on reading tests** over the course of one year, compared to students in classrooms with the least daylighting. The study also found positive and highly significant daylighting effects in the Seattle and Fort Collins districts, even though the three districts studied have different curriculums, different school building designs and different climates.

A panel of experts reviewed the original study and was generally satisfied with the soundness of the methodology and the rigor of the statistical analysis. The reviewers, however, expressed two primary concerns: Were "better" teachers more likely to be assigned to classrooms with more daylighting, thereby confounding the results? And would the analysis be more accurate if performed by grade level rather than aggregating data from four grade levels?

¹ Heschong Mahone Group (1999). Daylighting in Schools. An investigation into the relationship between daylight and human performance. Detailed Report. Fair Oaks, CA.
(http://www.h-m-g.com/Daylighting/daylighting_and_productivity.htm)

REANALYSIS EFFORT CONFIRMS AND EXPANDS ORIGINAL RESULTS

Prompted by a desire to answer these questions, to validate the rigor of the analysis, and to expand this important research, in 2000 HMG received funding to reanalyze the original study data. The ensuing report presents the methodology and findings of this reanalysis effort. Here, in brief, are the most significant conclusions:

- **Did the reanalysis study validate the original student learning rate findings?** Yes. The reanalysis study found that elementary school students in classrooms with the most daylight showed a 21% improvement in learning rates compared to students in classrooms with the least daylight. This is highly consistent with the range of findings in the original study.
- **Were the original results biased because "better" teachers are assigned to classrooms with more daylighting?** No. Better teachers were not significantly more likely to be assigned to classrooms with more daylighting.
- **Does this daylighting effect vary by grade?** No. There do not seem to be progressive effects as children get older, and younger children do not seem to be more sensitive to daylight than older children.
- **Do physical conditions in the classroom affect student health?** When student attendance is used as the measurement of student health, there is not an obvious connection between physical classroom characteristics (daylighting conditions, operable windows, air conditioning and portable classrooms) and student health.
- **What are the physical classroom characteristics that teachers most prefer?** Teachers had an almost universal desire for more space, a good location, quiet environment, lots of storage and water in the classroom. Windows, daylight and views were desirable but were not driving preferences.
- **Might other factors still be the reason for the variation on test scores?** A wide range of factors potentially affect student test scores, but of the many variables we studied only daylighting showed a strong correlation to improved standardized test scores. All these results were observed with 99.9% statistical certainty.

RIGOROUS STATISTICAL ANALYSIS APPLIED TO ORIGINAL AND NEW DATA

The reanalysis effort consisted of four research tasks: a teacher survey, a teacher bias analysis, a grade level analysis, and an absenteeism analysis.

The **TEACHER SURVEY** collected information from a sample of teachers in the Capistrano school district about their education, teaching experience, and preferences for classroom features. The survey's primary purpose was to inform the subsequent "assignment bias" analysis. The survey also revealed useful

information about teacher preferences, attitudes and behaviors in response to classrooms conditions.

While the teachers surveyed generally preferred classrooms with windows, daylight and views, they considered other classroom features — more space, a good location, quiet, lots of storage and water in the classroom — to be far more essential.

Environmental control was also important. Teachers expected to be able to control light levels, sun penetration, acoustic conditions, temperature and ventilation in their classrooms. They made passionate comments about the need for improvement if any of these conditions could not be controlled.

For the Teacher **BIAS ANALYSIS**, the teacher survey data was statistically analyzed to determine if the original study had over-inflated the effect of daylight on student learning by not accounting for a potential "assignment bias" of better teachers to more daylit classrooms.

We conclusively found that there was not an "assignment bias" influencing the results. A few types of teachers, those with more experience or honors, were slightly more likely (1%–5%) to be assigned to classrooms with more windows or some types of skylights. But considering all teacher characteristics together only explained 1% of the variation in assignment to daylit classrooms.

When we added the teacher characteristics to the original student performance models, the daylight effect was not reduced in significance. We identified a 21% improvement in student learning rates in classrooms with the most amount of daylight compared to those with the least.

In the **GRADE LEVEL ANALYSIS**, we reanalyzed the original student test score data for both Capistrano and Seattle by separate grade level, instead of aggregating the data across grades 2 to 5.

The data showed neither an increase nor decrease in daylight effects by grade level. There do not seem to be progressive effects as children get older, nor do younger children seem to be more sensitive to daylight than older children. Looking at aggregated data across grade levels, we conclude, is a sufficiently accurate methodology.

In the **ABSENTEEISM ANALYSIS**, we used absenteeism and tardiness data in the original Capistrano data set as dependent variables and evaluated them against the full set of explanatory variables from the original study, plus the new information on teacher characteristics. These models allowed us to assess whether daylighting or other classroom physical attributes potentially affected student health, as measured by changes in student attendance.

Student attendance data is certainly not the best indicator of student health. Yet to the extent that attendance data does reflect student health, our findings do not suggest an obvious connection between physical classroom characteristics and student health. Notably, daylighting conditions, operable windows, air

conditioning and portable classrooms were not found to be significant in predicting student absences.

LEARNING RATES

In summary, the availability of daylight in classrooms was reliably associated with an increase in student performance and learning rate in the range of 7% to 37%. The central tendency among all the models studied would be a 25% improvement in reading and a 16% improvement in math, or a 21% general improvement between children in classrooms with the most daylight compared to those in classrooms with the least.

Based on these results, if the average student in the district were moved from a classroom with an average amount of daylight to a classroom with maximum daylight, we would expect his or her learning rate to increase by 11%.

FUTURE STUDY WILL ATTEMPT TO REPLICATE RESULTS IN ANOTHER DISTRICT

Overall, these reanalysis efforts affirm that the effect of daylight on student performance is highly significant. Such consistent results present a powerful argument that there is a valid and predictable effect of daylighting on student performance.

The addition of more information to the statistical models did very little to change the predicted impact of daylight on student performance. Thus, we believe that it will be much more informative to try to replicate this study with a different population, at a different school district, than to continue to refine the models with further details and variables. With funding from the PIER program, we have already embarked on a new study with another school district, and look forward to presenting those results in 2003.

The full report is available at www.newbuildings.org/pier