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A need for evidence-based and multidisciplinary research to study the effects of the interaction of school environmental conditions on student achievement

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Green or high-performance buildings have been a topic of much discussion and research in the architectural engineering community since the 1990s. Of interest is the potential positive environmental impact when compared to standard building construction, as well as the belief that the indoor environments of such buildings can positively impact occupant comfort, performance and health. However, evidence-based research on claims of improving occupant outcomes is rather limited. Certain aspects of the built environment, including indoor air quality, thermal, lighting and acoustic conditions, have been linked to human comfort and performance, but only in a limited fashion as is apparent from the literature review provided in ASHRAE Guideline 10 "Interactions Affecting the Achievement of Acceptable Indoor Environments."[1] Furthermore, the majority of studies cited in this ASHRAE guideline have investigated the effects of only one or two human-comfort-related environmental variables at a time, without considering how the multitude of environmental variables may interact with each other. Nor do they consider how human behaviour may adapt in an integrated environment.

Rigorous research on how green or high-performance schools in particular may impact the performance and/or health of students and teachers is also not extensive.[2] Previous studies in this area can generally be categorised as two types: those that have relied on subjective surveys of the built environment, rather than physical objective measurements and those that have focused on a relatively small number of samples with periodic physical measurements. Examples in the former group include Earthman et al.,[3] Hines,[4] Durán-Narucki.[5] Results from these studies using opinion-based surveys do indicate improved student outcomes with better built environments, but unfortunately often cannot provide accurate predictions of that relationship. Investigations in the latter group tend to focus on only one or two aspects of the built environment; Schneider[6] and Baker and Bernstein[7] provide reviews of such work. Although some do find relationships between building attributes (e.g. the indoor air quality, thermal, lighting, or acoustic conditions) and improved academic outcomes, too many draw conclusions from indirect measures (health or performance through absenteeism, for example), from ill-designed experiments with a lack of statistical rigour, or from anecdotal evidence.

With funding from the U.S. Environmental Protection Agency's (EPA) Healthy Schools initiative, a research team from the University of Nebraska– Lincoln (UNL) is currently working on establishing how environmental conditions in K-12 school buildings impact student scholastic achievement. The objectives of the research project are: (1) to study comprehensively the impacts of a wide set of indoor environmental factors (including indoor air quality, thermal, lighting and acoustic conditions) on student achievement; (2) to investigate how these environmental conditions interact with each other to impact student achievement; (3) to rank order the environmental variables in terms of their relative impact on student achievement and (4) to determine how these effects vary with different demographic (e.g. socio-economic) groups.

Importance of school environment and novelty of the research

According to 2013 statistics from the United States Department of Education, about 50 million students attend 98,800 public elementary and secondary schools, in the U.S.[8] In the past decade, over $20 billion has been spent annually, on average, on school construction.[7] However, large numbers of school facilities and classrooms are still in poor shape, and these poor building conditions may be negatively affecting student performance and health.

Children in particular are more susceptible than adults to negative impacts from their environment.[9,10] One example is that they are more susceptible to environmental pollutants than adults because they breathe higher volumes of air relative to their body weights.[11] They also require higher acoustic signal-to-noise ratios to achieve the same speech intelligibility scores as adults, due to the level of their cognitive development and lack of vocabulary.[12] Not only are children more sensitive than adults but classrooms are more crowded than offices, and children have fewer ways of registering complaints.[13] The few studies that have been performed on children regarding health and performance due to thermal and ventilation conditions have shown similar results as those for adults,[14,15] but other aspects of the indoor environment were not included in those studies. As the focus of much previous research has been on only a few indoor environmental factors at a time, and their effects on occupant satisfaction and performance,[1] there is a lack of understanding about higher order interactions between combinations of all of these indoor environmental factors and their impacts on human comfort and performance. This project proposes to fill this significant information gap, with emphasis on K-12 classrooms.

The UNL research team currently gathers environmental data from a large number of local in-use K-12 classrooms throughout different seasons, and plans to link that data to student achievement outcomes, student absenteeism rates and demographics. Many previous studies have involved laboratory studies that allow control of environmental conditions, but subjects only occupy and perform tasks in the space for some short time period.[16] The novelty of the proposed research is that in-situ data are being mined from existing classrooms and correlated to actual student achievement outcomes. The difficulties with running this research in the past have included (a) forming a research team with the wide-ranging expertise required in indoor air quality, thermal, lighting, and acoustic conditions, as well as statistical analysis and (b) gaining access to classrooms for detailed measurements and access to student achievement data. The research team has established a good working relationship with local school systems, and they provide the required access and student data. Dr. Lily Wang, the principal investigator and an acoustic expert, has joined with her colleagues Dr. Clarence Waters, a lighting expert and Dr. Josephine Lau, an indoor air quality expert, to oversee the gather detailed environmental measurements from more than 200 classrooms in the mid-west region. The educational psychologist, Dr. James Bovaird, will subsequently use sophisticated statistical tools to correlate each condition, as well as the complex interplay of conditions, with student performance on standardised tests. This collaboration provides the technical expertise across the broad range of disciplines necessary for this study.

Authors' contributions — All authors contributed equally in the preparation of the literature review and draft of the paper and to the research ideas presented, while Josephine Lau and Lily Wang led the final revision and editing of the manuscript.

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