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Editorial

Advancing a multidisciplinary research framework on school environment, occupant health, and performance

The United States has the one of the highest annual expenditures per student among OECD countries, yet enrollment in early childhood education, high school graduation rates, and metrics of educational proficiency rank at or below average (OECD, 2014). As human capital investments are a primary driver of economic growth (Blundell et al., 1999, Tsai et al., 2010), governments have sought to develop effective educational policies and appropriate public investment strategies to augment citizens' social and economic potential.

The subsequent political dialog regarding school performance improvement has focused on the delivery of education, whether through creation of educational standards (Porter et al., 2011), incentivizing teacher performance (Goodman and Turner, 2010), administrative restructuring of schools (Heckman, 2000), or increasing competitiveness of school markets (i.e., voucher programs) (Figlio and Hart, 2014). Currently, absent from the national debate is the role of health in performance of school occupants. Although a positive association between student health and educational achievement has been established in the academic literature (Basch, 2011; Forrest et al., 2013; Magzamen et al., 2013), findings have been difficult to contextualize due to the fragmented nature of research on school occupant well-being and performance. These disparate lines of inquiries can be classified generally into two main areas of consideration: (i) physical health, which concerns environmental quality; and (ii) psychological health, which has focused on the role of organizational culture. The disjointed scholarship on school occupant health, well-being, and performance may accurately reflect the disciplinary boundaries of academic research, but results in a siloed literature with a paucity of comprehensive evidence to guide policy decisions. Below, we briefly review major contributions and limitations of each field.

Intervention studies across international settings have demonstrated a relation between school indoor environmental quality (IEQ) and physical health outcomes (Kim et al., 2013; Meklin et al., 2002, 2005; Mendell et al., 2013; Myhrvold et al., 1996; Norbäck et al., 2011; Smedje and Norbäck, 2001; Smedje et al., 1997). Further, cross-sectional studies have found associations between IEQ and educational outcomes (Bakó-Biró et al., 2012; Haverinen-Shaughnessy et al., 2011; Myhrvold et al., 1996; Shaughnessy et al., 2006) including proximate cognitive measures, such as computerized task performance (Satish et al., 2012; Twardella et al., 2012), which may directly impact student achievement. A critical review of the literature has suggested that student health and subsequent absence mediates the relation between poor IEQ and student performance (Mendell and Heath, 2005). While general consensus for healthy learning environments exists, the complexity of poor IEQ, including chemical and nonchemical stressors, has complicated identification of common causal pathways between the physical environment and educational outcomes.

A parallel literature has focused on effects of a positive school social milieu, which has been identified as a key element for school improvement (Muijs et al., 2004). Within the educational sociology literature, the term 'school climate' refers to the organizational culture of a school, including occupant attitudes and behaviors (Thapa et al., 2013). Research has demonstrated a positive association between school climate and student psychosocial health (Kuperminc et al., 1997; Larusso et al., 2008; Patton et al., 2003; Shochet et al., 2006) and a negative relationship between school climate and absenteeism (Gottfredson and Gottfredson, 1989; Rumberger, 1987). In addition, the link between school climate and academic achievement has been established empirically (Hoy and Hannum, 1997; Hoy et al., 1990; Macneil et al., 2009). One of the main challenges of school climate research is measurement: there are over 100 distinct survey tools that measure school social culture (Gangi, 2009). School climate has multiple dimensions (e.g., order, domain, and safety; school connectedness) (Zullig et al., 2010) that are not consistently evaluated across surveys. Much like IEQ, the concept of school climate is multifaceted. However, unlike IEQ, exposure assessment for school climate relies solely on subjective measures and perception. Choice of a meaningful survey tool in addition to selection of an appropriate target population for response adds additional dimensions of complexity to research on the role of school climate on occupant performance.

Clearly, both IEQ and school culture are critical aspects of positive learning environments. However,

there are limited studies that consider the interaction of these factors on school performance, which complicates the identification of the causal pathway(s) through which these exposures operate. The most common link between the two domains has been studies of facility quality. Researchers have posited that inadequate school facilities inhibit the perception of a serious learning environment and community engagement that encourages achievement (Uline and Tschannen-Moran, 2008). Studies have shown that sustainably built schools increase student and community pride in the school, in conjunction with decreases in bullying and staff turnover (Edwards, 2006; Rudd et al., 2008). However, additional research has shown that academic achievement predicts students' connectedness to school (Waters et al., 2010), leading to questions about the direction of the association. Absenteeism has been found to mediate the relation between facility quality and student performance (Durán-Narucki, 2008), although other IEQ factors were not considered. In one of the most comprehensive studies published, Uline and Tschannen-Moran (2008) found that teachers' rating of school social climate mediates the relation between school facility quality (as measured by teacher perception of building appearance, adequate space for activities, and timely maintenance schedules) and student achievement (as measured by students standardized test scores) (Uline and Tschannen-Moran, 2008). Although the study lacked objective measures of IEQ, the conceptual model that links the physical and social environments suggests a potential template for understanding the design of optimal learning environments.

There are real and perceived impediments to the integration of school IEQ and social climate research. First and foremost, a disciplinary language barrier results in multiple interpretations of key terms. For example, the National School Climate Center defines school climate as 'the quality and character of school life…based on patterns of students', parents', and school personnel's experience of school life and reflects norms, goals, and values…(National School Climate Center, 2015)'. Although the use of the term school climate to describe school social culture has existed in the academic literature for almost forty years (Brookover et al., 1978), the phrase undoubtedly has distinct meaning in engineering parlance (i.e., climate control) and has been associated with regard to a facility's energy footprint and aspects of sustainable design (i.e., adaptation for global climate change.) In a similar vein, the Collaborative for High Performance Schools identifies 12 aspects of 'high performance schools', which focus primarily on design and efficiency features (Collaborative for High Performance Schools, 2006) and does not include human dimensions of performance, such as educational achievement or workplace satisfaction. This lack of integration between disciplines is not unique to the study of schools: although technological innovation has fostered the importance of human-centered design (Nemeth, 2004), the social and technical aspects of these endeavors are 'split off (Rosenbrock, 1989)'. Although collaborative perspectives are necessary to understand and rectify pressing societal needs, these disciplinary boundaries are profoundly institutionalized and permeate professional organizations and their respective principles. In short, 'social scientists read what social scientists have written; engineers read what engineers have written (Klein, 1989)'.

Given the current state of the research, we call for an integration of social sciences, environmental and occupational health sciences, and engineering to understanding the role of health and well-being in school occupant performance. We have identified four major areas for collaborative work that can contribute to this field.

Study design

The IEQ and school climate literature are replete with cross-sectional and ecological studies, which are suggestive, but have limited interpretation and inference. There is a great need for more experimental, quasi-experimental, or longitudinal studies that would allow for meaningful insight of potentially causal relationships, and greater insight regarding the direction, magnitude, and relation (i.e., confounding, mediation, moderation) among covariates and exposures. Given the significant increase in school choice movements across OECD countries (Musset, 2012), the research community is well positioned to move beyond hypothesis generation and design sophisticated, efficient studies that leverage current trends in delivery of primary and secondary education.

Occupational health

The physical and psychological health of employees is a critical factor in job performance (Darr and Johns, 2008, Hakanen et al., 2006). Student academic performance cannot be understood comprehensively without consideration of the impact of IEQ and school climate on the health and well-being of teachers. Occupational health studies provide valuable insight on the relative contribution of physical and social aspects of the work environment on employee health and productivity. Although IEQ has been associated with teachers' report of somatic symptoms in a number of studies (Mazurek et al., 2008, Muscatiello et al., 2015, Sahakian et al., 2008), recent data suggest that physical symptoms reported at work are independent of IEQ and associated with job stress and job dissatisfaction (Black et al., 2014). Student psychological health and low levels of school satisfaction have demonstrated an association with teacher absenteeism (Ervasti, 2012), whereas positive school climate appears to have a protective effect

for teacher burnout and is associated with high levels of professional satisfaction (Grayson and Alvarez, 2008).

Measurement

As mentioned previously, exposure assessment for IEQ and school climate is complex. In addition, the endpoints of studies vary widely: health outcomes range from global measures such as absence to subclinical measures such as lung function, while educational outcomes are measured through standardized tests, grades, or performance on experimental tasks. The field would greatly benefit from the development of a 'master concept', or consensus on exposures that are relevant to occupant performance and well-being, as well as development of common outcome measures. Given the development of national educational standards in the United States (Kendall, 2011), and existence of established standards in other OECD nations, in addition to available measures of health (e.g., absentee data), there may be common metrics that may be used across studies and countries to help disentangle the relation among the physical environment, psychosocial environment, health, and performance. In addition, specific to IEQ assessment, subjective assessment may augment information derived through objective measurement. A school-based study found that perception of poor air quality was greater among teachers dissatisfied with the facility's psychosocial climate (Smedje et al., 1997).

Confounding

Factors that influence school health and performance are also influenced by multiple social and dynamic factors in addition to intrinsic covariates, particularly parental education and socioeconomic status (SES) (Entwisle et al., 2005; Ou and Reynolds, 2008; Sirin, 2005). School facility quality, student health, and student performance likely reflect the overall socioeconomic status of a community based on funding provided by state and local governments (Condron and Roscigno, 2003). For schools with poor IEQ, low health status among occupants, and comparatively low achievement, it is likely that there are exogenous exposure variables—poor ambient air quality (Green et al., 2004; Wu and Batterman, 2006), soil and water contaminants, poor housing stock, crime, lack of social cohesion in the surrounding community—that play a role. To adequately address issues of identifiability, the research community should endeavor to collect relevant health, performance, and covariate data at multiple levels, including individual student, classroom, school, and community. However, the broader issue for both researchers and policymakers is if school-level interventions and sustainable design can improve children's health and/or student performance given other environmental and social risk factors at the household or neighborhood level. Deteriorating school facilities may reflect larger economic inequality issues that may result in an inverse multiplier effect. One major unresolved question is if potential improvements in school-based social and environmental interventions would be effective or meaningful within the greater context of community-based social and environmental issues.

Given shifts in demographics, the advent of new educational technology and concern regarding the energy footprint of public buildings and structures, design and redesign of school facilities will be a major infrastructure investment for many municipalities in the near future. The fragmentary nature of the prior literature must be improved upon to allow for more effective policy recommendations and to truly ascertain whether improvements in school facilities will benefit students, teachers, and other occupants. Because much of the prior literature suffers from the methodological limitations outlined above, clear policy recommendations about effective school interventions cannot yet be made. In the United States alone, there are 50 million public school children who spend close to 1000 h in the classroom per year (OECD, 2013), in addition to 3.1 million public school teachers (National Center for Educational Statistics, 2013), 40% of whom have been in the profession 15 years or more (Feistritzer, 2011). We advocate for a multidisciplinary research approach to develop holistic evidence-based practice and policy to promote the health, well-being, safety, and success of the world's students and teachers.

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