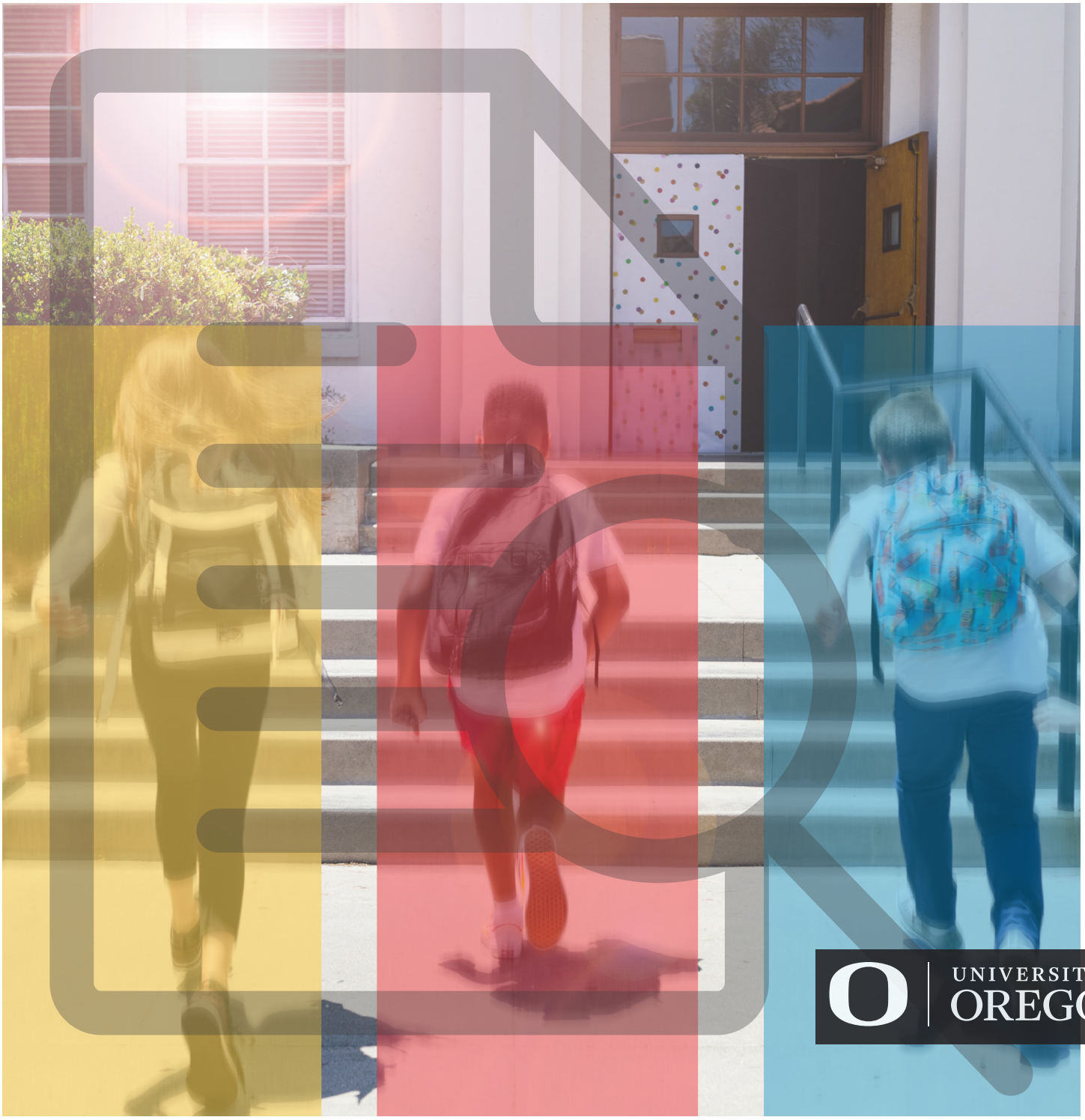
THE IMPACT OF SCHOOL FACILITIES ON STUDENT LEARNING AND ENGAGEMENT

Net ZED
Case Study Lab
annotated bibliography



UNIVERSITY OF OREGON

Annotated Bibliography

The Impact of School Facilities on Student Learning and Engagement

Prepared for

California School Facilities Research Institute

Prepared by

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Net ZED Case Study Lab

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About the Annotated Bibliography

One of the objectives of the California School Facilities Research Institute's (CSFRI) project is to examine the current state-of-knowledge regarding the impacts of school facilities on student engagement and learning. Researchers with the NetZED Laboratory in the Department of Architecture and College of Education at the University of Oregon gathered more than 500 publications through a systematic review of the literature, with specific focus to the impacts of the school environment on student engagement and learning. Researchers used this review of literature to develop a white paper titled, "Impacts of School Facilities on Learning and Engagement." Included in this bibliography are dissertations, journal articles, conference papers, reports, literature reviews, case studies about the built environment. Criteria for selection included: relevancy to the objectives, peer-reviewed documents, TK-12 school facilities, though some university classrooms were included, and international in scope. This bibliography is limited to the works found during the grant period in 2021. CSFRI anticipates expanding this bibliography into dynamic, living database, as new research is conducted and the field. Eighteen subject areas related to the indoor environmental quality, spatial environment, and people and community factors of school facilities.

1. School Facilities and Learning
2. Indoor Environmental Quality
3. Thermal Comfort
4. Indoor Air Quality
5. Microbes / COVID
6. Thermal Comfort and IAQ
7. Light
8. Views and indoor nature
9. Acoustics
10. Connection to the outdoors / outdoor learning / Physical activity
11. School and classroom size
12. Interior design (Color, Openness, spatial characteristics)
13. Furniture, Technology, Flexible spaces and Active learning
14. Pedagogy
15. Participatory design
16. Universal Design for Learning – Special Education
17. People / socialization – in between spaces
18. Safety and Security

For each entry, a summary is included with the following information so that users will understand the scope of work of the publication.

Publication type: Journal article, Commentary, Report, Book, Doctoral Dissertation
Study type: Literature review, Field study, Meta-analysis, Systematic Analysis, Research Study, Experimental study, Quasi-experimental study, Secondary analysis, Theory development
Sample: number
Duration: Cross-sectional, Longitudinal, Single point in time
Age or developmental stage: grade and/or ages.

We have provided Digital Object Identifier (DOI) numbers for most of the citations, which is a unique number for online publications. Many historical documents do not have DOIs. Access to publications is dependent on several factors, most importantly copyright of intellectual property held by the publisher or the author. Users will need to go through publisher paywall to obtain many of the documents, or if the article is available through Open Access, it will be free and immediate.

The following visual symbols are used to rapidly identify literature types.

Journal Article or Conference Proceedings
Research from peer-reviewed journals or conference proceedings

University Publication
Research from universities, including thesis research

Reports
Reports issued by third parties

Periodicals
Digital or published magazine articles

Books or Book Chapters
Print or e-books

Industry & Professional practice
Resources from professional practice

Standards
Codes, standards, product category rules

School Facilities and Learning

Apriesnig, J. L., Manning, D. T., Suter, J. F., Magzamen, S., & Cross, J. E. (2020). Academic stars and Energy Stars, an assessment of student academic achievement and school building energy efficiency. *Energy Policy*, *147* (September), 111859. https://doi.org/10.1016/j.enpol.2020.111859

This paper studies the relationship between student productivity and energy efficiency, as well as the relationship between school characteristics and student health and behavioral outcomes. The study used an existing database that included environmental data, energy star data and tests score data from the Colorado School District from students grades 3-12. The data included end-of-grade standardized test scores, ethnicity, gender, and variables such as nurse visits, suspensions, and expulsions. Also, student variables, School IEQ variables, School EUI variables and other school variables were included. Four regression models were created to describe different relationships within the data. The study rendered no significant associations between energy efficiency and student performance, but it did find positive associations between thermal and visual comfort and student performance. The authors state that the results they present "should reassure administrators that such retrofits will not counteract the academic impacts of funding dedicated to expanding educational resources for students." [1]

Publication type: Journal article
Study type: Secondary analysis
Sample: 47 schools, data from 3 previous years
Age or developmental stage: grades 3-10

Baars, S., Schellings, G. L. M., Krishnamurthy, S., Joore, J. P., den Brok, P. J., & van Wesemael, P. J. V. (2021). A framework for exploration of relationship between the psychosocial and physical learning environment. *Learning Environments Research, 24(1), 43–69.* https://doi.org/10.1007/s10984-020-09317-y

Researchers describe two existing frameworks in education - the Psychosocial Learning Environment (PSLE) and the Physical Learning Environment (PLE). The authors' aim is to review literature related to these two frameworks to determine a guiding relationship between them. A better understanding of the interaction between PSLE and PLE can inform the relationship between the physical environment and personal factors like mental well-being and learning. Authors reviewed relevant literature on PSLE, PLE, and other related topics on the relationship between the two. The authors broke PSLE down into sub-dimensions of personal development, relationships, and system maintenance and change; and the PLE into sub-dimensions of naturalness, individualization, and stimulation (mentioned in other relevant articles). The researchers put together a set of visual diagrams and tables identifying the overlapping areas where the two frameworks interact. [2]

Publication type: Literature review
Study type: Theory development

Barrett, P., Zhang, Y., Davies, F., & Barrett, L. (2015). Clever Classrooms. Summary report of the HEAD Project (Holistic Evidence and Design) (February issue).

The HEAD (Holistic Evidence and Design) project suggests that physical characteristics of classrooms account for a 16% variation in student's learning (the original study evaluated 3,766 students in the UK over one year). Overall, the major finding in the report is that students learning the subjects writing, reading, and mathematics are greatly impacted by physical environments categorized by the authors into naturalness, stimulation, and individualization (SIN). For "naturalness," the study showed that light, temperature, and air quality account for almost 50% of the learning performance difference seen in students. Next, individualization, which is shown through ownership and flexibility, accounted for 25% of the performance increase. The last environmental measure, stimulation, measured through color and complexity, accounted for the remaining 25% of performance difference. In conclusion, classroom design matters more than whole school factors, in terms of student performance. [3]

Publication type: Report
Study type: Field study
Sample: 153 classrooms, 27 schools, 3766 students
Duration: Longitudinal, One year
Age or developmental stage: 5 to 11

Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning. Building and Environment, 59, 678–689. https://doi.org/10.1016/j.buildenv.2012.09.016

In this study, the authors focused on the impact of school design on child learning in primary schools. Seven hundred fifty-one students from seven different schools in the UK were evaluated on their performance (Environment Human Performance, EHP) and other variables such as the classroom and school level. Next, using a research method called HEAD (Holistic Evidence and Design), the researchers broke down the different school environments into three categories: naturalness, individualization, and level of stimulation. The findings showed that this model (HEAD) was able to account for over half of the learning improvements seen in the children, with 73% of the variation explained by six built environment factors such as color, choice, connection, complexity, flexibility, and light. Overall, this study helps to clarify the different school facility variables that impact learning. [4]

Publication type: Journal article
Study type: Field study
Sample: 751 students in 7 schools
Duration: Longitudinal, One year
Age or developmental stage: 2-19 years

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. Building and Environment, 89, 118–133. https://doi.org/10.1016/j.buildenv.2015.02.013

This paper evaluated the results of the HEAD project, indicating that physical factors such as stimulation (color, complexity), individualization (ownership, flexibility), and naturalness (light, temperature, and air quality) account for variations in student performance. The study used data from 153 classrooms, 27 schools, and 3766 students. The study found that over 50% of the impact on learning came from naturalness, while the other two parameters only accounted for a quarter of the influence each. The study found that Light, Temperature, Air Quality, Ownership, Flexibility, Complexity and Color accounted for 16% of the variation. The authors highlight the importance of inside-out design. They highlight that the effects of single parameters should not be isolated to develop the analysis. While each factor varies in terms of its significance to boosting performance, the study demonstrates how the factors work together to produce an overall holistic design approach to classroom design. [5]

Publication type: Journal article
Study type: Field study
Sample: 153 classrooms, 27 schools, 3766 students
Duration: Longitudinal, One year
Age or developmental stage: Years 1 to 6

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2017). The Holistic Impact of Classroom Spaces on Learning in Specific Subjects. Environment and Behavior, 49(4), 425–451. https://doi.org/10.1177/0013916516648735

In this HEAD (Holistic Evidence and Design) study, the authors measured the progress of students in kindergarten through 5th grade. Using the stimulation, individualization, and naturalness SIN model, further identified in a previous study, they were able to evaluate the physical environment's effects on student performance. The results show that light and flexibility greatly impact all parameters of performance, complex space and color are at the optimum level of effectiveness in the middle ranges, connections to nature significantly impacted writing, ownership was related to math progress, and that stimulating environments impact reading and writing performance. Overall, these environmental factors influence 10% of the variability of student performance. [6]

Publication type: Journal article
Study type: Field study
Sample: 153 classrooms, 27 schools, 3766 students
Duration: Longitudinal, One year
Age or developmental stage: 5 to 11

Barrett, P., Treves, A., Shmis, T., Ambasz, D., & Ustinova, M. (2018). The Impact of School Infrastructure on Learning. A Synthesis of the Evidence.

This report presents a summary of current research on how school infrastructure affects student learning from a variety of perspectives. One

of the main sources of data of this report is the Clever classrooms study from 2015 in the UK. This report identifies key parameters to inform the design, implementation and supervision of future school facilities. Among their findings are that safe and healthy schools are important for students' academic outcomes. Similarly, they touch on the fact that schools should be close to their students, remain relatively small communities, have small class sizes and low student densities to generate maximum benefits for student performance. The report also mentions the duration of classes and optimal scheduling between classes as important for educational purposes. According to the authors, other factors should also be considered to create better spaces for learning including good "natural" conditions, age-appropriate learning spaces, spaces that are easy to read, adequate levels of ambient stimulation using color and complexity, designs from the inside-out, and considering local culture and climatic conditions. The report considers that there is potential to upgrade existing schools using reasonable resources, and that new schools should be designed with learning as a priority. Finally, the report makes the case that flexible spaces are important for student learning, and that multiple stakeholders and the school community should be part of the design and planning of new facilities. [7]

Publication type: Report
Study type: Literature review

Berman, J. D., McCormack, M. C., Koehler, K. A., Connolly, F., Clemons-Erby, D., Davis, M. F., Gummerson, C., Leaf, P. J., Jones, T. D., & Curriero, F. C. (2018). School environmental conditions and links to academic performance and absenteeism in urban, mid-Atlantic public schools. *International Journal of Hygiene and Environmental Health*, 221(5), 800–808. https://doi.org/10.1016/j.ijheh.2018.04.015

Berman, McCormack, Koehler, Connolly, Clemons-Erby, Davis, Gummerson, Leaf, Jones, and Curriero address how the environment in and around schools affected student absenteeism and academic performance. The methods involved in this study involved 158 urban schools in the Baltimore City public school system that had grades 3-5 and 6-8. The school climate survey, community characteristics, and environmental data were collected and measured at each school. Students were tested on their academic performance with the Maryland School Assessment (MSA). The school environmental data was measured with the U.S. EPA Risk-Screening Indicator (RSEI) that showed toxic substance risk at each site. The roadways around the school were measured with information from the U.S. Census Bureau. The research study found that a change in each 10-unit facility condition index resulted in a decrease in math and reading scores. The study also found that chronic absences increased with the worse quality buildings. The EPA's Risk Screening Environmental Indicator found that an increase in it created a significant, marginally, trend of more absences. [8]

Publication type: Journal article
Study type: Research Study
Sample: 158 schools
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Grades 3-5 and 6-8

Blackmore, J., Bateman, D., Loughlin, J., O'Mara, J., & Aranda, G. (2011). *Research into the connection between built learning spaces and student outcomes. Education Policy and Research Division, Department of Education and Early Childhood Development, East Melbourne, Victoria.* http://hdl.handle.net/10536/DRO/DU:30036968

This review covers over 700 papers to investigate the effects of school facilities on academic outcomes. To develop the review, the authors developed a theoretical framework including different phases of the school facility including the design phase, implementation and transition phase, consolidation phase, and sustainability/ re-evaluation phase. The review focused on the most current literature at the time, from 2000 to 2010. They found an uneven distribution on the research literature, as thy found it was mostly concentrated in the design phase, and little in the following phases. They also state that much of the literature focuses on perceptions and quality of conditions, but not on educational practices, use of space and its effects.[9]

Publication type: Journal article
Study type: Literature review

Bluyssen, P. M. (2017). Health, comfort and performance of children in classrooms - New directions for research. *Indoor and Built Environment, 26(8), 1040–1050.* https://doi.org/10.1177/1420326X16661866

This paper presents a literature review with salient topics on how school facilities affect student learning. The review found that most of the existing studies focused on the main four IEQ factors, namely IAQ, thermal comfort, light and noise. Nonetheless, indoor air quality parameters, such as ventilation or emissions seemed to have a prevalent role. The review pointed out the difficulty of arriving to strong conclusions given the multi-factorial nature of the problem and the diversity of the existing research. It stated that the available research failed to look at the interactions between different factors. In addition, the review points towards the need to develop more experimental, quasi-experimental and longitudinal studies, as well as to use qualitative methods such as focus groups to get more insight on the problem of school facilities and student performance. Finally, the review concludes that the next generation of research should focus of how to customize the classroom for children, for new ways of teaching and for new technologies. The review states that "user engagement is key for defining and solving problems in the classroom" [10]

Publication type: Journal article
Study type: Literature review

Bowers, A. J., & Urick, A. (2016). Does High School Facility Quality Affect Student Achievement? A Two-Level Hierarchical Linear Model. University of Illinois Press, 37(1), 72–94.

This paper investigates the relationship between the quality of school facilities and student achievement. To do this, Bowers et al. analyzed the public-school component and the facilities checklist of the ELS 2002 survey, which includes 8110 students in 520 schools. For the analysis, they used a two-level hierarchical linear model and assessed the influence of the

quality of the facilities on students' growth in math standardized tests in their 2 final high-school years, while controlling for other variables. They found no independent effects of this relationship. Nonetheless, they did identify differences in student and school attributes by facility disrepair. They end by proposing a model, where facility quality mediates perceptions of the facility by different actors (teachers, students, parents, school leaders), which in turn affects school academic climate, which ends up affecting student achievement. [11]

Publication type: Journal article
Study type: Secondary analysis
Sample: 8110 students in 520 schools
Age or developmental stage: grade 10 and 12

Campos, P. (2020). Resilience, education and architecture: The proactive and "educational" dimensions of the spaces of formation. International Journal of Disaster Risk Reduction, 43. https://doi.org/10.1016/j.ijdrr.2019.101391

Campos addresses how education is affected by learning spaces and how spaces can reinforce resilience in school environments. The methods involved in the text showed the United Nations belief surrounding resilience and measuring how the composition of architecture affects school designs and reinforces resilience. The research studied affective action and awareness, sustainability, and community. There was also a focus on harmony, order, planning, color, and art and how resilience relates to those topics. There was a measurement on the value that education gains from resilience and if that they can create an educational and resilient space with schools. The research paper found that a large area where projects could increase resilience was in the typologies of models, plans, geometry, proportions, treatment of vertical and horizontal walls, limits, ordering axes, and types of section and natural light. The research paper also found the main ally of resilience for the creation of educational value, motivational learning, and increase in well-being is architecture that is properly planned. [12]

Publication type: Journal article
Study type: Research Paper
Sample: NA
Duration: Cross-sectional
Age or developmental stage: School Age

Cencic, M. (2017). To what extent do school leaders in Slovenia understand physical school environments as a learning factor? *Center for Educational Policy Studies Journal, 7(2), 141–162.*

The author aimed to determine school leaders' perceptions about the impact of the physical environment of schools on several different educational attributes. The study uses an online questionnaire that was taken by 150 school heads in Slovenia; the schools involved included a range of old schools, newer ones, and recently renovated ones. The survey asked school heads to rate (on a 1-5 Likert scale) their perceptions of how the physical school environment impacts 14 different characteristics of school:

imagination, creativity, feelings, language, music, logic and mathematics, space, movement, ecology, aesthetics, cooperation among students, respect, ethics and attitude towards the broader community. Results from the questionnaire indicated that school leaders perceived the greatest impact from the physical environment as affecting ecology, movement, and respect, whereas the school environment impacts feelings, imagination, and space the lowest. Other factors including cooperation among pupils, language, ethics, and attitude towards the broader community also scored higher than average [13].

Publication type: Journal article
Study type: Research Study
Sample: 150 school heads
Duration: Single point in time

Chan, T. C. (1996). Environmental Impact on Student Learning. https://files.eric.ed.gov/fulltext/ED406722.pdf

This publication presents a summary of seven papers on the impact of school facilities on student learning which were originally published in Chinese in the eighties and have been translated to English. The first paper reviews seven papers from the sixties and seventies, where they find significant associations between building age and student achievement. The second paper looks at school design and instructional need, which includes interdisciplinarity, classroom flexibility and ADA needs. The third paper talks about the learning environment (LE) and student achievement. It states that the LE directly and indirectly impacts student achievement. It relates direct impacts with environmental and physical factors, and indirect impacts with psychological factors. This paper briefly presents the results of a study where the most modern LE had the highest achieving students in comparison with less modern or obsolete environments. The fourth paper is a commentary on the authors view of learning environments. The fifth paper presents 3 more studies on school building quality and student achievement. The first study used secondary information from elementary schools in Georgia and found that approximately 5% of the student achievement variance was attributed to school building quality. The second study focused on middle schools and found that this percentage was only 1%. The third study focused on high schools and found this percentage to be 12%. The sixth paper of the publication touches upon environmental psychology and Facility planning. The seventh and final paper is on educational facility research in America. [14]

Publication type: Publication
Study type: Summary
Sample: 7 papers

Choi, H. H., van Merriënboer, J. J. G., & Paas, F. (2014). Effects of the Physical Environment on Cognitive Load and Learning: Towards a New Model of Cognitive Load. *Educational Psychology Review* (Vol. 26, Issue 2, pp. 225–244). Springer New York LLC. https://doi.org/10.1007/s10648-014-9262-6

Choi, van Merriënboer, and Paas address how the physical environment

impact learning and the cognitive load of students. The article was focused on the idea that the cognitive load of the physical environment may be more impactful than specific physical characteristics. The methods involved in the article were the factors, such as task (environment), learner, their interaction, and the mental load, mental effort, and performance, combined to make up the cognitive load. The article involved multiple texts relating to five different sections. The article found that the physical environment impacts the cognitive load and learning because of its differences based on learner characteristics and learning-task characteristics. The article created a revised model of the cognitive load construct that helped connect the subjects and ideas. The study concludes that there are many arguments to treat the physical learning environment as a separate factor in cases in which it influences the cognitive load. [15]

Publication type: Journal article
Study type: Research Article
Sample: 1
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Primary to University

Clark, H. (2002). Building Education: The Role of the Physical Environment in Enhancing Teaching and Research. http://eric.ed.gov/?id=ED472377

This publication considers school buildings from different perspectives. First, it discusses school facilities, attainment, and behavior. Then, it covers how buildings that support and encourage participatory learning. It looks at how the school can be opened to the wider community, as well as inclusive schools for special educational needs children. Finally, it addresses environmental and technological concerns. The publication is centered in schools in the UK. [16]
Publication type: Book.
Study type: Design Guidelines

Cooper, I. (1985). Teachers' Assessments of Primary School Buildings: the role of the physical environment in education. *British Educational Research Journal*, 11(3), 253–269. https://doi.org/10.1080/0141192850110306

Cooper addresses how teachers view their work environment at school and what they think about it, as well as how teachers believe children are influenced in their learning because of the building design. The methods involved in this paper are case studies that relate to the perceptions of teachers about their built environment at school and how they believe children's education is influenced. There were 10 different school buildings where teachers gave information on the similarities, differences, and perceptions. The paper found that teachers do not believe their built environment that surrounds them at school can properly serve them and allow them to best manage and practice their teaching skills. The paper also found that in the case studies some teachers believed that the built environment at school was detrimental to education and learning. The paper also found that the state of the school may be talked about amongst teachers, which would increase their emotions and potentially influence their perceptions. [17]

Publication type: Journal article
Study type: Literature Review/Research Paper
Sample: 10
Duration: Cross-sectional
Age or developmental stage: Primary

Dierkx, R. (2003). Toward community-based architectural programming and development of inclusive learning environments in Nairobi's slums. *Children, Youth and Environments, 13(1), 56–73.* http://www.jstor.org/stable/10.7721/chilyoutenvi.13.1.0056

The main goal of this paper is to offer a case study solution for low-cost, high-quality spaces for students in Nairobi to receive a better education. The author first sent questionnaires to teachers throughout 8 districts in Nairobi with varying qualities of schools. Next, he selected students from one school in each of the 8 districts and conducted a workshop, where students sketched diagrams of their ideal SHE school (Safe, Healthy, Environmentally inclusive). Finally, the author and an assistant conducted a baseline assessment of the quality of each of the schools where the field surveys were conducted. The study found that schools that had poor IAQ, acoustic environment, lighting, had no connection to nature resulted in in negative effects on student health, well-being, and decreased ability to learn. The author worked with students, parents, and teachers in one of the districts to design a "pilot school" which would incorporate more positive attributes and would be built at low cost, for other schools to emulate [18].

Publication type: Journal article
Study type: Research Study
Sample: 80 teachers in 8 districts. Students in one district.
Age or developmental stage: 13 and 14 years old (student workshops)

Durán-Narucki, V. (2008). School building condition, school attendance, and academic achievement in New York City public schools: A mediation model. Journal of Environmental Psychology, 28(3), 278–286. https://doi.org/10.1016/j.jenvp.2008.02.008

This study examines the role of school attendance as a mediator in the relationship between the quality of the facilities and student grades in city and state standardized tests. Durán-Narucki used data on building condition, and scores from English Language and Arts (ELA) and mathematics standardized tests. She included 95 elementary schools in New York City and controlled for ethnicity, social economic status, teacher quality, and school size. Data of building conditions was taken from the survey for New York City school buildings, and the School Report cards from the annual reports of the NYC Board of Education. The data was analyzed Baron and Kenny's (1986) approach for testing mediation hypotheses. The study found that attendance was a for mediator for scores in ELA, and a partial mediator for scores in math. Durán-Narucki proposes the idea that children are influenced by the school environment in three levels. The material level, which is the basic environmental level were cleanliness, repair, and all the Indoor Environmental Quality issues affect the basic needs of children in schools. All health problems are included in this level. The second level has to

do with his social interactions that students have daily interactions in school buildings, and that are affected by the condition of the building. Finally, the third level has to do with an "environmental meaning", where "conditions created in social and cultural contexts can produce collective and individual meaning." [19]

Publication type: Journal article
Study type: Secondary analysis
Sample: 95 elementary schools
Age or developmental stage: Elementary school

Edwards, B. W. (2006). Environmental Design and Educational Performance. *Research in Education, 76(1), 14–32.* https://doi.org/10.7227/rie.76.2

This study explores whether simply having a "green" school (ecologically sustainable) would relate to student performance and general overall well-being. The author identified 26 "green" primary schools in Essex and Hampshire, UK, and paired them with a control, traditional (not specifically sustainable) school. He then used student test scores to compare student performance between the two schools, as well as with the local and national averages. He supplemented this quantitative research with teacher interviews, to determine perceptions of the spaces. In most cases, students in green schools outperformed those in the control schools. The green schools also got better reviews in terms of lower stress levels, enjoyment in inhabiting the building, and relationships with others. The author identified three main takeaways: 1) green schools offer learning advantages, especially in younger children, 2) teachers and students tend to value inhabiting green schools, which lower stress, and leads to lower staff turnover, thus better performance and productivity, 3) specifically, access to daylight and sunlight seemed to have a significant correlation to performance and well-being [20.]

Publication type: Journal article
Study type: Research study
Sample: 26 schools
Duration: Single point in time
Age or developmental stage: Primary schools

Evans, G. W., Yoo, M. J., & Sipple, J. (2010). The ecological context of student achievement: School building quality effects are exacerbated by high levels of student mobility. *Journal of Environmental Psychology,* 30(2), 239–244. https://doi.org/10.1016/j.jenvp.2010.01.001

Using 511 NYC public schools, Evans et al. studied the impact of school facilities condition and student mobility on student achievement. They used existing structural quality data from the New York City Department of Education database on facility quality, using Likert scale ratings from building surveys. For academic achievement, they used reading and writing data from the New York City Annual School Reports, from students from 3rd to 5th grade. They used ordinary least squares regression and found that schools with low structural quality and high rates of mobility contributed to reduced academic achievement. Interestingly, racial, and socioeconomic conditions

were independent from the effects of building conditions on test scores. [21]

Publication type: Journal article
Study type: Secondary analysis
Sample: 511 NYC public schools
Age or developmental stage: 3rd to 5th grade

Haghighat, M. D., & Knifsend, C. A. (2019). The Longitudinal Influence of 10th Grade Extracurricular Activity Involvement: Implications for 12th Grade Academic Practices and Future Educational Attainment. Journal of Youth and Adolescence, 48(3), 609–619. https://doi.org/10.1007/s10964-018-0947-x

Haghighat and Knifsend address how students are affected by extracurricular activities and how they affect educational attainment and practices. The methods involved in this empirical study were 11,720 students involved in a longitudinal study that lasted 8 years. The study measured the students' abilities with cognitive tests and was given a self-report survey. The students were also given questionnaires that were applied three separate times. The students reported on their extracurricular activities and how involved they were in the study. Students were also asked how much they spent on homework, their educational expectations, and how much they attain educationally. The empirical study found that the length and intensity of the student's extracurricular activities caused the largest educational attainment when students start in 10th grade and were tested again 8 years later. The study also found that there was an increase in educational expectations for 12th graders when there was a long period spent doing extracurricular activities. [22]

Publication type: Journal article
Study type: Empirical Study
Sample: 11,720 students
Duration: Cross-sectional, Longitudinal, 8 Years
Age or developmental stage: 10th and 12th Grade

Herzog, S. (2007). *The ecology of learning: The impact of classroom features and utilization on student academic success.* New Directions for Institutional Research, 2007(135), 81–106. https://doi.org/10.1002/ir.224

Herzog addresses how students, and their success is affected by classroom utilization and features. The methods involved in this study are multiple classrooms with an average class size of 45 students at a university with first-year students. The measurements taken during this study occurred for four years and involved varsity athlete status, second-year retention, academic preparation, ethnicity and race, residency, age, parental income, math experience, English experience, Pell grant offers, millennium scholarship offers, institutional aid offers, average class start time, classroom windows, remaining need, average class size, average classroom density, average classroom size. The study found the students' abilities to learn were impacted and increased their ability to learn when there was increased use of information technology in a classroom. The study also found that room ambiance influenced academic performance. The study also found that student density, room size, and the presence of windows in classrooms all

affect students and their ability to learn. [23]

Publication type: Journal article
Study type: Case Study
Sample: 1 University, 45 students in average classroom
Duration: Cross-sectional, Longitudinal, 4 years
Age or developmental stage: University, first year students

Higgins, S., Hall, E., Wall, K., Woolner, P., & McCaughey, C. (2005). *The Impact of School Environment.* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.231.7213&rep=rep1&type=pdf

This is literature review on the impact of school environment on learning. The review was commissioned by the design council in the UK unsponsored by CfBT research and development. They use over 200 papers from seven different databases, referring to different aspects of the physical environment and learning. They use a framework that puts learning in the center, surrounded by four elements: environment, communication, products and services, and systems and processes. Most of the existing evidence points to individual elements but fails to seem to size understandings of the total environment. On the contrary, their findings point in these four directions and portrays the school as a larger system where different actors and settings interplay. They used these four elements to organize the information into 5 types off measures: attainment, engagement, affect, attendance, and wellbeing. [24]

Publication type: Report
Study type: Literature review

Kok, H., Mobach, M., & Omta, O. (2015). Predictors of study success from a teacher's perspective of the quality of the built environment. Management in Education, 29(2), 53–62. https://doi.org/10.1177/0892020614553719

Kok, Mobach, and Omta address how teachers view student success due to the built environment of the school. The methods involved in this research study were 1752 teachers at 18 different Universities and were given a national survey to address their belief of student success of the built environment. The measurements involved data analysis of functional and spatial aspects at institutions to address student success. 1752 questionnaires were analyzed to address the mean answer of teachers and how they viewed the success of students. The study found a positive relationship between student success and the perceived quality of classrooms, front office and ICT, classroom conditions, and cleanliness. The study also found that offices and meeting rooms or closed environments create more negative results of student success. The study also found that student success is dependent on the built environment that creates social interactions, is clean, and creates physical settings inside of large institutions. [25]

Publication type: Journal Article
Study type: Research Study
Sample: 18 Universities, 1752 teachers
Duration: Cross-sectional, Longitudinal

Age or developmental stage: University

Laura Healey Malinin, & Rosie Parnell. (2012). Reconceptualizing School Design: Learning Environments for Children and Youth. *Children, Youth and Environments, 22(1), 11.* https://doi.org/10.7721/chilyoutenvi.22.1.0011

The authors assess a number of papers relating to the physical environment of schools and the myriad impacts these can have on student learning. As part of a publication called Children, Youth, and Environments, the authors sent out a call for abstracts relating to school design and learning. They then selected a range of studies that most fit the bill and discussed their significance in modern school design. Notably, the authors categorized the literature into five "emerging themes": 1) Holistic education (social and emotional development issues), 2) Children's relationship with the natural world, in response to climate change, 3) Diversity and inclusive design for physical and cognitive difference, 4) Methods of engaging stakeholders in participatory design and construction, 5) Evidence-based design as best practice in the face of global economic crisis [26].

Publication type: Journal article
Study type: Literature review

Leiringer, R., & Cardellino, P. (2011). Schools for the twenty-first century: School design and educational transformation. *British Educational Research Journal, 37(6), 915–934.* https://doi.org/10.1080/01411926.2010.508512

The Building Schools for the Future (BSF) Initiative is the largest government initiative in 50 years in the UK to update/uprgade schools for the 21st Century. Leiringer and Cardellino, in conducting research to inform the BSF guidelines for school design/redesign, have conducted a multiple case study of four exemplar schools - two in Denmark and two in Sweden. The authors dissected the schools by focusing on three areas: the physical environment, how the facilities are used, and the design process. The resulting discussion focuses on the unique pedagogy at each of the schools, and the resulting design innovations, as well as a critical look at effect on student learning. While overall successful, certain aspects of these buildings' designs had drawbacks, and one must also consider the inherent differences between schools in Scandinavia, the UK, and elsewhere [27].

Publication type: Journal article, Commentary
Study type: Case studies
Sample: 4 schools

Lewallen, T. C., Hunt, H., Potts-Datema, W., Zaza, S., & Giles, W. (2015). The Whole School, Whole Community, Whole Child Model: A New Approach for Improving Educational Attainment and Healthy Development for Students. Journal of School Health, 85(11), 729–739. https://doi.org/10.1111/josh.12310

This paper presents the Whole school, Whole community, and Whole child model (WSCC). The framework comes from a combination of the Coordinated School Health (CSH) and Whole Child Model (WC). This approach has five

principles: each student enters school healthy and learns about and practice is a healthy lifestyle; each student learns in a physically and environmentally safe environment; each student is actively engaged in connected to a broader community; each student has access to personalized learning and has enough support; each student is challenged academically and prepared for success in college in prepared for the world.
The framework can be summarized as one where the student is in the center and is challenged, supported, engaged, safe and healthy. The approach is meant to be collaborative and includes employee wellness; physical environment; social and emotional climate; counseling psychological and social services; health services; nutrition environment and services; physical education and activity; health education; community involvement; and family engagement. [28]

Publication type: Journal article
Study type: Theory development

López-Chao, V., Lorenzo, A. A., Saorín, J. L., De La Torre-Cantero, J., & Melián-Díaz, D. (2020). Classroom indoor environment assessment through architectural analysis for the design of efficient schools. Sustainability (Switzerland), 12(5), 1–12. https://doi.org/10.3390/su12052020

López-Chao, Lorenzo, Saorín, De La Torre-Cantero, and Melián-Díaz address how the indoor environment of school affects the efficiency of school, learning spaces, and the perception of comfort. The methods involved in this manuscript were self-reported data, relationships between mathematics, art performance, and learning space for 583 primary schools in Galicia, Spain. The study measured with the Indoor Physical Environment Perception scale and it was conducted and adapted in 27 classrooms. The study measured with an Exploratory Factor Analysis and holistic studies that affect the indoor environment and differences in classroom designs. The manuscript found that the Exploratory Factor analysis found that three categories form a learning space. The three categories that form a learning space are workspace comfort, natural environment, and building comfort. The manuscript also found that the physical space affects the performance of math and art tasks. The manuscript also found that there are good levels in the primary classrooms in Galicia. [29]

Publication type: Journal Article
Study type: Manuscript
Sample: 583 Schools, 27 Classrooms
Duration: Cross-sectional
Age or developmental stage: Primary

McGregor, J. (2004). Spatiality and the place of the material in schools. Pedagogy, Culture and Society, 12(3), 347–372. https://doi.org/10.1080/14681360400200207

McGregor addresses how spaces in school interact with students, teachers, and support staff. Specifically, how the materials impact the order between the school and those who attend or work at the school. The methods involved in the research article were a research study and the ability of the atrial in

school to interact with the space and how it affected students and teachers. The article measured spatiality with the relationships between place and space and objects in the relation of space. The Actor Network Theories (ANT) measured the relationship between the material and the social and how the constructed environment is affected by simple cultural or symbolic artifacts. The research article found using that study that heterogeneous actors from the ANT are dependent on social relations and network relations. These relations depend on technology and the flow of people that produce space. The article also found that to create professional learning and better workplace relations there needs to be the addition of new considerations of space. [30]

Publication type: Journal Article
Study type: Research Article
Sample: 1 Research Study
Duration: Longitudinal
Age or developmental stage: Teachers and Students

Manca, S., Cerina, V., Tobia, V., Sacchi, S., & Fornara, F. (2020). The effect of school design on users' responses: A systematic review (2008-2017). *Sustainability* (Switzerland) (Vol. 12, Issue 8). MDPI AG. https://doi.org/10.3390/SU12083453

Manca, Cerina, Tobia, Sacchi, and Fornara address how students and teachers are affected by the school design, specifically their well-being, performance, and satisfaction. The methods involved in this study were at first, 1307 articles that were then narrowed down to 68 empirical papers. The papers were chosen based on indoor environmental features, classroom design, school green spaces and outdoor spaces, and architectural building design and aesthetic features. The measurements depended on different ages and types of students as well as teachers. The measurements were taken with the performance of students being tested, perception of well-being, and perception of satisfaction with their school environment. The systematic review found that the well-being and performance of students and teachers increased in flexible, warm, and pleasant learning spaces. The systematic review also found that ergonomic furniture, adequate acoustics, thermal comfort, and ventilation, with natural lighting, and the presence of charming colors and pictures should be considered in designs. [31]

Publication type: Journal Article
Study type: Systematic Review
Sample: 68 Papers
Duration: Cross-sectional, Longitudinal, 10 Years
Age or developmental stage: Primary through High School

Matthews, E., & Lippman, P. C. (2020). The Design and Evaluation of the Physical Environment of Young Children's Learning Settings. *Early Childhood Education Journal, 48(2), 171–180.* https://doi.org/10.1007/s10643-019-00993-x

The authors seek to review relevant literature to make a case for the built environment's effect on early childhood development and learning, and to make recommendations to designers and relevant stakeholders based on the

research. They highlight various design tools and metrics developed by other researchers, like Barrett's "Clever Classroom" checklist, as tools for educators and school designers to use. Various factors of the built environment, like noise/acoustics, spatial design, light, air quality, and circulation/legibility all operate individually and in synergy to influence the development, learning, and social outcomes for young children in early childhood educational environments. More direct research is needed to test each of these attributes; and of course, the built environment is one of several factors influencing child development, along with quality of the teachers, individual needs and characteristics, etc. [32.]

Publication type: Journal article
Study type: Literature review

Maxwell, L. E. (2016). School building condition, social climate, student attendance and academic achievement: A mediation model. *Journal of Environmental Psychology*, 46, 206–216. https://doi.org/10.1016/j.jenvp.2016.04.009

Maxwell addresses how the social climate, achievement academically, and attendance of students were affected by the condition of the school building. The methods involved in the mediation model were 236 New York City middle schools and a structural equation modeling that addressed the building and outcomes due to the condition of the building on students. The mediation model measured the social climate measured by the Learning Quality Survey, the attendance rate of students, the tests scores on English language and math standardized tests, the building conditions based on an assessment from professionals, the percentage of students who identified as a minority, and the percentage of students eligible for reduced and free priced meals. The mediation model found that achievement academically was affected by the social climate and attendance of students due to the building condition. The study also found that many students perceived their social climate as a positive experience that was affected by the physical space. [332]

Publication type: Journal Article
Study type: Mediation Model
Sample: 236 Schools
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Middle School

Michael, S. L., Merlo, C. L., Basch, C. E., Wentzel, K. R., & Wechsler, H. (2015). Critical Connections: Health and Academics. Journal of School Health, 85(11), 740–758. https://doi.org/10.1111/josh.12309

This is a review paper that aims at connecting different aspects of student health with academic achievement. It uses the whole school, whole community, and whole child model as a framework to highlight the critical connections between health and academic achievement. All the information comes from previous systematic reviews, metanalysis and unstructured literature reviews. It organizes the information in four categories. (1) supporting healthy student behaviors, including physical education nutrition environment and services and health education. (2) supporting school health

services, including health services counseling psychological and social services and employee Wellness. (3) supporting safe and positive school environments, including social and emotional school climate and physical environment. (4) Supporting the engagement of family and community, including family engagement and community involvement. They found that there are consistent findings on the relationship between physical activity an academic achievement. Also, there is an association between chronic conditions health services and decrease achievement. Safe and positive environments have a relationship with health behaviors and achievement. Finally, engaging families and communities into schools can have a positive effect on health and achievement. [34]

Publication type: Journal article
Study type: Literature review

Scott-Webber, L., Konyndyk, R., French, R., Lembke, J., & Kinney, T. (2017). Spatial Design Makes a Difference in Student Academic Engagement Levels: A Pilot Study for Grades 9-12. European Scientific Journal, ESJ, 13(16), 5. https://doi.org/10.19044/esj.2017.v13n16p5

Scott-Webber, Konyndyk, French, Lembke, and Kinney address how the built environment impacts the academic engagement levels of students. Specifically, if there is a way to demonstrate that the impact is related to engagement levels because of the spatial design. The methods involved in this pilot study were 25, 9 to 12 graders at a high school in the USA, 6 K-12 architects, 3 administrators, and 35 teachers. The study was focused on measuring the built environment and student academic engagement levels. The pilot study developed 15 questions submitted to those involved in the school to measure their perceptions and beliefs about the built environment and engagement levels. The pilot study found that students believed their engagement levels, overall and in the classrooms, were affected by the built environment and its design. The study also found that educators also believed that the built environment affected engagement levels. The study found there was a highly significant result that spatial design affects engagement. [35]

Publication type: Journal Article
Study type: Pilot Study
Sample: 25 students, 6 architects, 3 administrators, and 35 teachers
Duration: Longitudinal, Cross-sectional
Age or developmental stage: 9th through 12th Grade

Schneider, M. (2002). Do School Facilities Affect Academic Outcomes? In *National Clearinghouse for Educational Facilities, Washington, DC (p. 26).*

This review covers the impact of school facilities on student learning from six different angles: acoustics; lighting; thermal comfort, indoor air quality and ventilation; school size; classroom size; and building age and quality. It contains 134 references to make the case that the school facilities do have an effect on student learning. In the thermal comfort, ventilation and IAQ perspective it touches upon the issues of student absenteeism and poor IAQ, the ventilation problems in schools, and the growth of bacteria and mold due to high humidity, and their effects on student performance. Regarding lighting

it states that the consensus is that appropriate lighting improves student' test performance. Similarly, it states that good acoustics are essential for good academic performance. They state that there is consensus that newer buildings tend to contribute to higher student scores but warn that building quality and maintenance can be affected by budget limitations. In general, the evidence shows that small schools are better for student safety, attitudes, behavior, teacher attitudes and have been found to be cost effective. Finally, the review states that some studies consider class size to be more relevant than school size. In general, smaller classes appear to be better, but there is still a debate in the literature on what the appropriate class size is. The article ends by stating that better research is needed given the broad range of studies and methods found in the literature.[36]

Publication type: Report

Study type: literature review

Skinner, E. A., Kindermann, T. A., & Furrer, C. J. (2009). A motivational perspective on engagement and disaffection: Conceptualization and assessment of children's behavioral and emotional participation in academic activities in the classroom. Educational and Psychological Measurement, 69(3), 493–525. https://doi.org/10.1177/0013164408323233

Skinner, Kindermann, and Furrer address how the behavioral and emotional participation of children is affected by academic activities in the classroom. The methods involved in this research study were 1,018 students that were 3rd through 6th graders and measurements were taken of their emotional and behavioral participation. In the research, study measurements were taken from psychometric properties scores of student and teacher reports. Measurements were taken of behavioral disaffection, behavioral engagement, emotional engagement, and emotional disaffection. There was a structural analysis of the results from the measurements. The research study found that the scores are valid because the teacher reports are correlated with the student reports. Those reports are also in vivo with the observations from the classrooms and with the social contextual and self-system processes. The study also found that measurements were able to capture factors of disaffection and engagement in the classroom that can be studied more and compared. [37]

Publication type: Journal Article
Study type: Research Study
Sample: 1,018 Students
Duration: Longitudinal, Cross-sectional
Age or developmental stage: 3rd through 6th Grade

Simons, E., Hwang, S. A., Fitzgerald, E. F., Kielb, C., & Lin, S. (2010). The impact of school building conditions on student absenteeism in upstate New York. *American Journal of Public Health*, *100*(9), 1679–1686. https://doi.org/10.2105/AJPH.2009.165324

This study investigates upstate NY school building conditions and its relation to absenteeism. The authors merged data from 2 preexisting surveys from 2005: the Building Condition Survey and the State of Learning Annual Report (SED), which includes data on absenteeism. They used 2796 schools from

Upstate NY that had information in both the BCS and SED data sets. Using multivariate logistic regression, they found that absenteeism was associated with visible mold, poor ventilation, vermin, humidity, poor ventilation, six or more individual building condition problems, and building system or structural condition problems, with 95% confidence intervals. Schools from lower socioeconomic districts and with younger students had the higher associations. [38]

Publication type: Journal article
Study type: Secondary analysis
Sample: 2796 schools
Duration: Cross-sectional
Age or developmental stage: All – The schools is the unit of analysis

Smith, T. J. (2013). Designing learning environments to promote student learning: Ergonomics in all but name. Work, 44, 39–60. https://doi.org/10.3233/WOR-121493

Smith addresses how student learning and performance are dependent on the design of the learning environments. The methods involved in this report were two categories of performance factors. The first category involved 9 factors that have shown time after time to have a strong influence; environmental design of building facilities and classrooms, exposure to learning that is longer, learning cooperative designs, early childhood education, nutritional adequacy, quality of teaching, physical fitness and participating, and integration of the school and community. The second category involved 11 factors with varied, weak, or equivocal influence; online learning, a smaller class size, choice of school, funding for school, size of the school, start times of school, teacher training level, homework amounts, the self-confidence of students and informal learning. The report found that the learning outcomes of students and educators need to be considered in the design of the learning environment. The report also found that educational systems need to understand their role and how learning designs affect learning and performance. [39]

Publication type: Report
Study type: Research Study/Review
Sample: 20 Factors
Duration: Cross-sectional
Age or developmental stage: K through 12

Stornaiuolo, A., Nichols, T. P., & Vasudevan, V. (2018). Building spaces for literacy in school: mapping the emergence of a literacy makerspace. English Teaching, 17(4), 357–370. https://doi.org/10.1108/ETPC-03-2018-0033

Stornaiuolo, Nichols, and Vasudevan address how the understandings of literacy impact the building spaces of the school and how literacy should be considered in spaces that are being designed. The methods involved in this research study and paper were 1 public high school and two years of measurements and analysis of ethnographic data to understand the making, development, and uses of literacy-oriented makerspace in a school-based way. The study measured the mapping of literacy practice across different

areas and spaces to be of potential use in educational spaces. The research paper and study found that mapping, designing, and building a literacy lab in a space creates contested and layered purposes to enforce literacy across the school. The study also found that it may create frictions, but those fictions can be beneficial. The study also found that mapping gives resources to students to be able to access and remake the spaces they are a part of to use the built environment in more than one way. [40]

Publication type: Journal Article
Study type: Research Study/Paper
Sample: 1 School
Duration: Cross-sectional, Longitudinal, 2 Years
Age or developmental stage: High School

Szpytma, C., & Szpytma, M. (2019). Model of 21st century physical learning environment (MoPLE21). *Thinking Skills and Creativity, 34(April), 100591.* https://doi.org/10.1016/j.tsc.2019.100591

Szpytma and Szpytma performed an extensive literature review into the fields of educational research, psychology, and architecture. The goal of their review was to synthesize these three fields into a unified pedagogy of practice, acknowledging the role that the built environment has on education (and, by default, the psychology that connects these two). As a result of their research, the authors created the Model of 21st Century Physical Learning Environment (https://mople21.org) This dynamic document is intended for educational researchers, policymakers, educational practitioners, and architects to use in the design and implementations of schools in the 21st century and beyond. [41]

Publication type: Journal article
Study type: Literature review

Tanner, C. K. (2000). The influence of school architecture on academic achievement. *Journal of Educational Administration, 38(4), 309–330.* https://doi.org/10.1108/09578230010373598

This paper identifies 39 design patterns based on Christopher alexander "a pattern language" to measure the design of schools. The author uses four descriptors he associates with each pattern: functionality, adequacy of the pattern, safety associated with the pattern and quality of the pattern. The author devised an instrument to measure school design using the patterns. Schools with high scores would approximate to desirable learning environments. He used the instrument to assess 44 elementary schools in Georgia and related them to the ITBS standardized test scores. He found that some school patterns were significant predictors of achievement including technology for teachers, pathways or clearly defined areas for freedom of movement, overall impression of the learning environment, and positive outdoor spaces [42.]

Publication type: Journal article
Study type: Research study

Sample: 44 elementary schools
Duration: Single point in time

Tanner, C. K. (2008). Explaining Relationships Among Student Outcomes and the School's Physical Environment (Vol. 19).

The goal of this study was to investigate if there was a measured difference between spatial qualities of elementary schools (divided into four sets of design patterns) and student achievement (as measured via ITBS scores). The researcher and his team identified 24 elementary schools in Georgia, USA, serving ~11,500 students. The research team took in-depth tours of each school and scored the schools' design patterns divided into four categories: 1) movement and circulation, 2) large group meeting places, 3) Daylighting & Views, and 4) Instructional neighborhoods (patterns adapted from Alexander's "A Pattern Language"). The researchers then used publicly available student scores from the ITBS to determine if there was a link between spatial attributes and student achievement. In each of the cases, there was a positive correlation between student test scores and qualities or patterns of the schools deemed to be desirable or positive, although in some cases the relationship was more pronounced than others [43].

Publication type: Journal article
Study type: Research study
Sample: 1,916 students
Duration: Single point in time
Age or developmental stage: 3rd grade

Tanner, C. K. (2009). Effects of school design on student outcomes. Journal of Educational Administration, 47(3), 381–399. https://doi.org/10.1108/09578230910955809

In this study they compare student achievement using three school design classifications: movement and circulation day lighting and views. They studied 71 schools and used the Iowa test of basic skills (ITBS) in six different areas: reading comprehension, reading vocabulary, language arts, mathematics, social studies, and science to assess student performance. They assess how the physical environment affects student outcome using reduced regression analysis. They found significant effects for reading vocabulary, reading comprehension, language arts, mathematics, and science. Movement and circulation patterns, natural light, and views to the outdoors had an impact on student outcomes. They found significances for the design classifications of movement, circulation, and a lighting in different areas of the ITBS test. Their results are not consistent with other previous studies such as the Heschong Mahone Group study on lighting. The study leaves out other indoor Environmental Quality parameters such as acoustics indoor air quality and thermal comfort.[44]

Publication type: Journal article
Study type: Field study, Cross-sectional
Sample: 71 schools, 10,650 students
Age or developmental stage: 5th grade students

Terlevi~, M., Isteni~ Star~i~, A., & Šubic Kova~, M. (2015). Sustainable spatial development in higher education. *Urbani Izziv, 26(1), 105–120.* https://doi.org/10.5379/urbani-izziv-en-2015-26-01-004

The authors conduct a thorough literature review that (somewhat abstractly) considers the importance of sustainable development in the design of schools, including primary and secondary, and higher education. They are careful to note the holistic use of the word sustainable, as involving not only environmental factors, but also economic, social, and cultural factors. The authors review a number of articles that consider the importance of holistic sustainability in school design. They stress that the main building users - students (i.e. children and teens) are the future leaders in society, so nurturing their sense of holistic sustainability is crucial for a healthy world in the future. Notably, the authors bring up the fact that too many of today's young people (i.e. students) have a narrow sense of the word sustainability, thinking only of environmental sustainability, without internalizing the economic, social, and cultural factors. Also, today's young people think of sustainability as only being important for future generations, when in reality it is important for those of us alive today but also for higher education institutions, which have been rapidly including sustainable development in their educational process in the last two decades. Directly or indirectly, education for sustainable spatial development includes all aspects of sustainable development: environmental, economic, social and cultural. Space is a junction of various interests, which requires coordinating the entire process of spatial planning, taking into account the goal of sustainable spatial development. The existing values of space are insufficient for the rapid implementation of a sustainable spatial development paradigm. Suitable education is needed by both individuals and spatial planning professionals and at all levels of education. It is therefore necessary to transform some of the academic programs in the higher education curriculum by integrating teaching content and methods that include long-term knowledge and holistic thinking, taking into account the importance of interdisciplinary integration. This article reviews literature in sustainable development in higher education from 2002 to 2013. Topics discussed include students' and teachers' conceptions of sustainable development, the presence of sustainable development and sustainable spatial development in higher education and the reasons for the slow introduction of this material into the curriculum. Based on a literature analysis, the last section identifies important drivers that can contribute to a more rapid integration of a sustainable spatial development paradigm into higher education.[45]

Publication type: Journal article
Study type: Literature review
Sample: 32 articles

Thomson, D. (2016). The Short Run Impact of the Building Schools for the Future Programme on Attainment at Key Stage 4. April 16-07.

This paper compares the student attainment in schools that were renovated vs. schools whose renovation projects were cancelled in the Building Schools for the Future program (BSF). The BSF was a 15-year program in the UK that was cancelled after 6 years. The study uses academic datasets

covering 10 academic years. The paper compares attainment in schools that were completed vs. schools were the program was cancelled (treatment vs. comparison), as well as attainment in schools before and after the treatment (difference-in-differences).
Through linear regression, conditional difference-in-differences and 'within-between' random-effects regression to assess relationship between the variables, the study found that results from the various model were broadly similar and showed that new school buildings had no effect on pupil attainment, at least in the short-term. Nonetheless. When allowing for heterogeneous impacts, they found a small lagged effect in the earliest cohort of BSF schools. [46]

Publication type: Working paper
Study type: Secondary analysis
Age or developmental stage: Years 7 to 11

Tse, H. M., Learoyd-Smith, S., Stables, A., & Daniels, H. (2015). Continuity and conflict in school design: a case study from Building Schools for the Future. Intelligent Buildings International, 7(2–3), 64–82. https://doi.org/10.1080/17508975.2014.927349

Tse, Leoroyd-Smith, Stables, and Daniels address how a school design was created and built to address the conflicts and continuity in school design. Specifically, how to build schools for the future. The methods involved in this case study were one primary school created by the Labour Government's Building Schools for the Future Programme (DfES 2003, 2004) and how there was an educational value that was strategically placed to create a school for learning. The study measured the design phases across a long period and how a school for the future would be created with the exploration of design processes. Measurements were also taken of interview transcripts and literature on the factors being discussed. The case study found that the aims and objectives of the design and building process change the motives depending on the time in the development. The study found that tensions are created when different professionals want different steps to be taken to achieve a building for the future. [47]

Publication type: Journal Article
Study type: Case Study
Sample: 1 School
Duration: Longitudinal, 2 Years
Age or developmental stage: Primary

Ucci, M., Law, S., Andrews, R., Fisher, A., Smith, L., Sawyer, A., & Marmot, A. (2015). Indoor school environments, physical activity, sitting behaviour and pedagogy: A scoping review. Building Research and Information, 43(5), 566–581. https://doi.org/10.1080/09613218.2015.1004275

Ucci, Law, Andrews, Fisher, Smith, Sawyer, and Marmot address how pedagogical approaches and physical activity and sitting are impacted the indoor environment of a school. Specifically, where there are gaps in the previous literature collected on the topics of sitting behavior, physical activity, and indoor school environments. The methods involved in this scoping review were, at first, 4,818 articles, and then it was narrowed down to 58

articles depending on criteria that met the topics and added to the missing parts of the discussion. The review measured physical activity in schools for students. The review also measured sitting behavior in schools and how it compared across the literature. The review also measured the indoor school environments of schools and analyzed them in comparison with each other. The scoping review found that physical activity benefited the academic behavior and academic performance of primary students. The review also found that the indoor school environment needs to be investigated more thoroughly. [48]

Publication type: Journal Article
Study type: Scoping Review
Sample: 58 Articles
Duration: Longitudinal, Cross-sectional
Age or developmental stage: 2 to 11 Years Old and 11 to 16 Years Old

Uline, C., & Tschannen-Moran, M. (2008). The walls speak: The interplay of quality facilities, school climate, and student achievement. Journal of Educational Administration, 46(1), 55–73. https://doi.org/10.1108/09578230810849817

This study examines the relationship between school facility quality and student performance and proposes that this may be mediating school climate. The authors developed surveys to 80 Virginia middle school teachers using 5-point scales. They created a construct to understand the hypothesized relationship, where they included the following aspects of the school physical environment that affect achievement: Building condition and building features such as building age, climate control, indoor air quality, lighting, acoustical control, design classifications, and overall impression. They also included aspects of the school social environment (school climate) having to do with student achievement such as learning climate, teacher behavior and attitudes, principal leadership, and community ties. They found a link between student achievement in English and mathematics and quality of the facilities. School climate mediated the relationship between facility quality and student achievement. The quality of the facilities was unrelated to the leadership of the principal and to the social economic status of the students. Perceptions of the quality of the facilities were strongly correlated to resource support. Finally, they found that cleanliness and neatness were an independent factor of building quality. [49]

Publication type: Journal article
Study type: Research Study
Sample: 80 Virginia middle school teachers
Duration: Single point in time

Ulrich Jr, D. T. (2015). An Investigation of the Relationship Between Expenditures for Routine Maintenance and Deferred Maintenance and Student Achievement in Fresno County Unified Public School Districts.

This dissertation seeks to explore the relationship between school maintenance in K-12 schools and student learning. The study worked with 17 school districts in Fresno County. English Language Arts (ELA) and

mathematics California Standards Test (CST) between 2008 and 2013 for grades 3, 6, 8 and 10 was used for the analysis. Maintenance was measured by the percent of the general fund used on overall maintenance. The schools were classified according to the federal free and reduced lunch program to incorporate socio-economic status into the analysis and determine if maintenance expenditures were based on each district's socio-economic status. The study concluded that there was no relationship between the overall maintenance and scale score growth on CST. Also, it didn't find significant differences between schools from different socioeconomic groups. Nonetheless, by studying a confounding variable, the study found that facility capital and student learning were positively related for 3 of the 10 CST tests.[50]

Publication type: Doctoral Dissertation
Study type: Secondary information analysis
Sample: 17 school districts
Age or developmental stage: Grades 3, 6, 8 and 10

Scott-Webber, L., Konyndyk, R., French, R., & French, J. (2018). Significant Results . Space Makes a Difference Increasing Student Academic Engagement Levels. *European Scientific Journal, ESJ, 14(16), 61.* https://doi.org/10.19044/esj.2018.v14n16p61

This study investigated the effect of the school physical environment on student engagement in grades 9 to 12. They developed a POE and used mixed methods research working with students and teachers in four high schools in the US. They created two indexes to measure engagement: the student engagement index and the teacher engagement index. They found that for educators the overall culture of the school was more important than the physical environment. Nonetheless, they also found a significant effect of the physical environment on engagement and teaching and learning practices for teachers and students. They concluded that the design of a space made a difference and increased student academic engagement. [51]

Publication type: Journal Article
Study type: field study
Sample: 4 high schools, n = 462 students, n = 137 educators
Duration: single point in time
Age or developmental stage: 9 to 12 grades

Woolner, P., Hall, E., Higgins, S., McCaughey, C., & Wall, K. (2007). A sound foundation? What we know about the impact of environments on learning and the implications for Building Schools for the Future. Oxford Review of Education, 33(1), 47–70. https://doi.org/10.1080/03054980601094693

This paper presents a literature review of the impact of environments in learning in schools studying over 200 references in depth. The authors detect 5 kinds of effects on learning: attainment, engagement, affect, attendance, and wellbeing. They organize their findings into positive, conflicting, and negative effects. There is less information on the positive effects of the built environment. They study environmental factors on the 3 categories: lighting, IAQ, noise, room arrangement and furniture, temperature, color,

build quality (subjective aesthetic subjective assessment/ spatial features like high ceilings), display and storage. They found that there is not enough evidence to give clear guidance to policy makers on how to prioritize funding for schools, or to evaluate the monetary value of different design initiatives. Some environmental improvements are related with improvements in student achievement, but it is important to keep in mind the complexity of environmental interactions once these measures reach the standards. Aspects of flexibility and adaptability are important for the design of schools, as they may respond to new approaches and challenges. Qualitative variables also need to be considered when understanding the impacts of the environment on learning. There is lack of empirical evidence about the individual impacts of elements of the physical environment at a practical level to support student achievement. Environmental change can be a catalytic process of school development and improvement. [52]

Publication type: Journal article
Study type: Literature review

Woolner, P., Thomas, U., & Tiplady, L. (2018). Structural change from physical foundations: The role of the environment in enacting school change. *Journal of Educational Change, 19(2), 223–242.* https://doi.org/10.1007/s10833-018-9317-4

This research adds to a debate about the significance of the physical environment in the implementation of "school change" in a theoretical framework of culture, structure, and individual action. The researchers identify two primary schools in the UK as case study schools. The two schools underwent a process of change, implementing new curricula and pedagogical styles. Both schools also enacted changes in the physical environments of the learning spaces. The researchers conclude that the physical environment is part of the puzzle in enacting a wholesale change in schools' conceptual frameworks of culture, structure, and individual action/ agency. Simply implementing a new curriculum or pedagogy on its own is not as impactful as altering the physical environment; conversely, simply altering the physical environment alone is not as impactful as implementing a new pedagogy, culture, etc. [53.]

Publication type: Journal article
Study type: Case study, Theory development
Sample: 2 schools

Zhang, D., & Bluyssen, P. M. (2021). Energy consumption, self-reported teachers' actions and children's perceived indoor environmental quality of nine primary school buildings in the Netherlands. *Energy and Buildings, 235, 110735.* https://doi.org/10.1016/j.enbuild.2021.110735

Zhang and Bluyssen wanted to understand the relation of occupants and their energy use throughout the day. They looked at the relationship of the teachers, students, and the use of the classroom lights. Data collected was from perceived and measured IEQ for the lighting and the teachers use of the light switch. The schools were in various areas in the Netherlands with various energy consumption between them throughout the year. What

Zhang and Bluyssen found was that the higher the measured illuminance, the more energy that was used. On the other end though, the more the lights were used, the more the kids complained about the IEQ and therefore the teachers would adjust the lighting. Zhang and Bluyssen found that the more active that the teachers were in using the light switch meant that they had a better chance at reducing the electricity that the buildings used. [54]

Publication type: Journal article
Study type: Field study
Sample: 9 schools, 26 classrooms, 593 student questionnaires, 26 teacher's questionnaires
Duration: Single point in time
Age or developmental stage: primary schools

Jenkins, P., Phillips, T., & Waldman, J. (2004). *California Portable Classrooms Study (Vol. 6, Issue November).*

In this report, the California Air Resources Board and the Department of Health Services present the results of a cross sectional study performed both in traditional and portable classrooms in California. They looked at the IEQ conditions in classrooms from kindergarten to 12 grades considering existing guidelines and standards for ventilation, noise, lighting, formaldehyde, lead dust, asbestos, radon, and mold. They used a mail survey and found that there were approximately 80.000 portable classrooms in California. In the phase 1 of the study, they gathered information on facilities and teachers from 384 schools. The facility questionnaire included classroom and school level data. They also did physical measurements in a subsample of schools. In phase 2 they developed physical measurements in 67 of the initial sample of schools. Their findings include classroom and school characteristics, building materials and other pollutants, environmental problems, building operation and maintenance, classroom ventilation, air pollutants, moisture and mold, pollen, noise, lighting, and thermal comfort. The study found that both portable and traditional classrooms had IEQ problems. Nonetheless, the study stated that most of the solutions needed were low cost and would go a long way with improved operation and maintenance. Among the main recommendations of this report are quieter HVAC units and low emitting building materials. The study also recommends 4 approaches to tackle IEQ problems which are: 1) direct and assist schools to comply with state regulations, 2) develop and promote best practices for schools' design, maintenance and operations, 3) improve support for facilities and staff 4) establish guidelines for school environmental health.[55]

Publication type: Report
Study type: Field study
Sample: 384 schools
Duration: Single point in time
Age or developmental stage: K to 12 classrooms

Frumkin, H. (Ed), Geller, R. J. (Ed), Rubin, L. (Ed) & Nodvin, J. (Ed). *Safe and Healthy School Environments. (Oxford University Press (OUP), 2006).*

This book covers the environment of the school and concentrates on health and safety from multiple perspectives. It provides information on the physical environment of the school, and then makes an emphasis on multiple topics that are critical for health. Among these are indoor air quality, toxic hazards, nutrition and physical activity, violence and disasters, transportation to and from school, school management and school health services. The book is based on the idea that schools are spaces where there is an opportunity to promote children's' health, as they can prevent disease and promote wellbeing. [56]

Publication type: Book
Study type: Literature review

Indoor Environmental Quality

Altomonte, S., Allen, J., Bluyssen, P. M., Brager, G., Heschong, L., Loder, A., Schiavon, S., Veitch, J. A., Wang, L., & Wargocki, P. (2020). Ten questions concerning well-being in the built environment. *Building and Environment*, *180*, 106949. https://doi.org/10.1016/j.buildenv.2020.106949

This document crates an argument for different directions of research and a new model regarding well-being and health in the built environment. To do this, experts answer ten questions arguing for a change in the focus of studies regarding well-being in the built environment. For them, wellbeing needs to shift from a negative (no harm) perspective to a positive (delight) approach. To achieve this, they propose simultaneous considerations of positive outcomes regarding environmental performance, human preference, and experience. They say that new considerations should include having an integrated analysis approach that accounts for the individual occupant and for transient conditions over time. They advocate for the creation of opportunities for well-being. They say this might demand a "reconstruction of the field from its fundamentals", and a paradigm shift from the way the field has developed so far in scholarly articles and in the general press. However, despite this surge in attention, there are still many questions on how to effectively design, measure, and nurture well-being in the built environment. Bringing together experts from academia and the building industry, this paper aims to demonstrate that the promotion of well-being requires a departure from conventional agendas. The ten questions and answers have been arranged to offer a range of perspectives on the principles and strategies that can better sustain the consideration of well-being in the design and operation of the built environment. Placing a specific focus on some of the key physical factors (e.g., light, temperature, sound, and air quality.[57]

Publication type: Journal article
Study type: Literature review

Brink, H. W., Loomans, M. G. L. C., Mobach, M. P., & Kort, H. S. M. (2021). Classrooms' indoor environmental conditions affecting the academic achievement of students and teachers in higher education: A systematic literature review. *Indoor Air*, 31(2), 405–425. https://doi.org/10.1111/ina.12745

This paper is a literature review of the impact of IEQ on higher education, which it uses the same framework and methodology to organize the studies as (Mendell, 2005). They identify relevant information by searching on multiple databases and select 21 publications that show positive or negative effects of IEQ. Their evidence suggests that IEQ can contribute positively to the quality of learning and short-term academic performance of students. They state that the influence of IEQ parameters on the quality of teaching, and the long-term academic performance could not be determined. Students' performance is task dependent and varies depending on the IEQ conditions. Their findings suggest that classrooms that provide multiple IEQ conditions may facilitate different types of learning. [58]

Publication type: Journal article
Study type: Literature review
Number of studies: 21 studies

Dorizas, P. V., Assimakopoulos, M. N., & Santamouris, M. (2015). A holistic approach for the assessment of the indoor environmental quality, student productivity, and energy consumption in primary schools. *Environmental Monitoring and Assessment, 187(5), 1–18.* https://doi.org/10.1007/s10661-015-4503-9

This paper presents a field study that investigates students' performance, perceptions on IEQ, and energy consumption in primary schools. The study includes physical measurements and questionnaires to assess thermal comfort, ventilation rates, relative humidity, air pollutants, acoustics, sick building syndrome and lighting. The study included 9 naturally ventilated primary schools, where field measurements were registered during 32 days between April and May. A total of 193 11-year-old students participated in the survey, and 665 questionnaires were collected. Math and code tests were administered to students to investigate student performance. Finally, yearly data on energy consumption for electricity and oil for heating was collected for 8 of the 9 schools. A cluster analysis was carried out to determine the ranges of IEQ parameters at which the students were satisfied with the indoor environment. The study found that most students were satisfied with IEQ. Also, increased levels of particulate matter didn't affect perceptions of IAQ, but temperature and humidity variations did seem to affect IAQ perceptions. Students were found to prefer a cooler environment. Pm and CO2 concentrations were correlated with respiratory health effects, and girls seemed to be more sensitive than boys. CO2 negatively affected test scores. Students were satisfied with light and acoustic levels. Finally, the study found that energy consumption was positively correlated levels of indoor pollutants. [59]

Publication type: Journal article
Study type: Field study
Sample: 9 primary schools, 193 students
Duration: 32 days of measurements, repeated tests, and questionnaires
Age or developmental stage: 11-year-olds

Fisher, K. (2001). Schooling Issues Digest Building Better Outcomes: The Impact of School Infrastructure on Student Outcomes and Behaviour. *Australian Dept. of Employment, Education, Training and Youth Affairs, Canberra.* http://www.detya.gov.au/schools/publications/2001/index.htm.

This report covers a series of papers dealing with the impact of the school environment on student learning. It touches on building age, building condition, school size, color, thermal conditions, air quality, furniture, lighting, and acoustics. The review also presents an interesting matrix of socio-spatial factors in school design covering formal and informal learning spaces, as well as indoor and outdoor spaces. The review concludes that by 2001most of what was known about the relationship of school infrastructure and learning was theoretical, rather than proven relationships. Only very specific issues like lighting, acoustics, air quality and temperature had more conclusive research. Therefore, the review concludes that there is a need to develop more empirical research on this topic. [60]

Publication type: Report
Study type: Literature review

Gilavand, A., Espidkar, F., & Gilavand, M. (2016). Investigating the Impact of Environmental Factors on Learning and Academic Achievement of Elementary Students: Review. *International Journal of Pediatrics, 4(4), 1663-1670.* https://doi.org/10.22038/ijp.2016.6672

This paper presents a literature review that examines the impact of schools' open space, noise, lighting, and paint in schools on learning and academic achievement of elementary students. The authors found 252 articles on carefully chosen databases, since the year 2000. They selected 39 of those, based on medical education experts' advice. Two investigators analyzed the data independently. Their results show that noise has a negative effect on learning, while color, light, and open space have a positive effect. They conclude that environmental factors are important for the design of schools.[61]

Publication type: Journal article
Study type: Literature review
Sample: 39 papers

Hviid, C. A., Pedersen, C., & Dabelsteen, K. H. (2020). A field study of the individual and combined effect of ventilation rate and lighting conditions on pupils' performance. *Building and Environment, 171.* https://doi.org/10.1016/j.buildenv.2019.106608

In this study they investigated the combined effects of dynamic lighting and ventilation rates on children concentration, math skills, processing speed and logical reasoning. The study looked at combined exposures of low ventilation rates (3.9 l/s per person) and high ventilation rates (10.6 l/s per person) with warm light CCT of 2900 K and 450 lux or dynamic cool light CCT 4900 K and 750 lux. A total of 92 students 10 to 12 years old participated in the study over four weeks and answered different questionnaires and performance tests. Among the tests were the d2 concentration test, the Baddeley test for logical reasoning, and math assessments including multiplication and subtraction. They found significant improvements ($p < 0.01$) in concentration,

processing speed, and math skills in the scenario with high ventilation rates and dynamic cool lighting. The logical reasoning tests didn't show significant changes. The study showed that pupils were satisfied with the classrooms, but the environmental changes didn't affect these perceptions. [62]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 92 students, four classrooms
Duration: 4 weeks
Age or developmental stage: 10 to 12 years old

Issa, M. H., Rankin, J. H., Attalla, M., & Christian, A. J. (2011). Absenteeism, performance and occupant satisfaction with the indoor environment of green Toronto schools. *Indoor and Built Environment, 20(5), 511–523.* https://doi.org/10.1177/1420326X11409114

This study compared the absenteeism, performance an occupant satisfaction in energy retrofitted schools, green schools, and conventional schools in Toronto. The authors used data from a sample of 10 conventional, 20 energy-retrofitted and three green schools. For the first part of the study, they collected student, teacher, and staff absenteeism data, as well as Grade 3 and 6 student performance data on reading, writing and arithmetic tests administered by Ontario's Education Quality and Accountability Office. On the second phase of data collection, they conducted an IEQ satisfaction survey with 150 teachers. Their analysis showed that "teachers in green schools were in general more satisfied with their classrooms and personal workspaces' lighting, thermal comfort, indoor air quality, heating, ventilation and air conditioning than teachers in the other schools. Nevertheless, they were less satisfied with acoustics." They also found that student, teacher, and staff absenteeism improved by 2–7.5% in green schools, and student performance improved by 8–19% when compared with conventional schools. [63]

Publication type: Journal article
Study type: Field study
Sample: 10 conventional, 20 energy-retrofitted and 3 green schools. 150 teachers.
Duration: Single point in time, secondary data on absenteeism and performance from a single year
Age or developmental stage: Grades 3 and 6

Marchand, G. C., Nardi, N. M., Reynolds, D., & Pamoukov, S. (2014). The impact of the classroom-built environment on student perceptions and learning. *Journal of Environmental Psychology, 40, 187–197.* https://doi.org/10.1016/j.jenvp.2014.06.009

This study assessed the effects of the classroom indoor environmental factors of light, sound and temperature on students' learning, mood, and perceptions of performance during listening and reading tasks. The study was performed in a laboratory where the students were exposed to optimal or suboptimal environmental conditions and had to develop a listening or a reading task. A total of 158 undergraduates participated in the study. They used the PANAS (Positive Negative Affect Scale) brief measure, a comprehension assessment, and a built environment experience survey as

measures for the experiment. They found that the sub-optimal environment was more detrimental to students performing listening tasks than reading tasks, even though the effect was small. They found partial support to the hypothesis that the built environment had an effect on participant affect, as they found no effects on positive mood from the environmental conditions or learning modality. Nonetheless, students outside the comfort zone reported more negative affect. They end by stating that it is possible that suboptimal built environment conditions may impact learning indirectly by affecting student mood or motivation.[64]

Publication type: Journal article
Study type: Experimental study
Sample: 158 students
Duration: Single point in time
Age or developmental stage: Undergraduate students

Ricciardi, P., & Buratti, C. (2018). Environmental quality of university classrooms: Subjective and objective evaluation of the thermal, acoustic, and lighting comfort conditions. *Building and Environment*, *127*, 23–36. https://doi.org/10.1016/j.buildenv.2017.10.030

In this paper, the authors study thermal, acoustic, and lighting comfort conditions of 7 university classrooms. They carried out physical measurements and developed specific questionnaires to assess students' comfort perceptions. The authors then used the qualitative data to compare to the questionnaire. They found no significant differences between the classrooms regarding thermal comfort. The analysis of the lighting questionnaire showed that the average measured illuminance value had a high correlation with the perceived visual comfort. Similarly, glare had a strong relationship to the classroom excessive light contrasts and a good correlation with the measured illuminance values. Among the acoustic and lighting questionnaires, the authors chose the ten questions with the best correlation with the experimental results and proposed ten indexes to describe the comfort conditions. [65]

Publication type: Journal article
Study type: Field study
Sample: 7 classrooms, 928 questionnaires
Duration: spring and fall
Age or developmental stage: Undergraduate students

Turunen, M., Toyinbo, O., Putus, T., Nevalainen, A., Shaughnessy, R., & Haverinen-Shaughnessy, U. (2013). Indoor environmental quality in school buildings, and the health and wellbeing of students. *International Journal of Hygiene and Environmental Health*, 217(7), 733–739. https://doi.org/10.1016/j.ijheh.2014.03.002

This study is aimed at understanding indoor Environmental Quality in Finnish schools. Authors used health questionaries to understand how IEQ impacted the health of 6th grade students. A sample off 297 elementary schools participated in the study, and a total of 4248 questionnaires were used for the analysis. A sample of 56 schools was used to measure the actual

indoor environmental conditions. They found that the most common weekly symptoms were fatigue, stuffy nose, and headache. Also, the most frequently IEQ factors listed as causing daily problems where noise, and poorer air quality, perceptions of high temperature, and dust or dirtiness. The results show that classrooms might have low ventilation rates and high indoor temperatures according to student perceptions. 66stuffy nose (7.3%

Publication type: Journal article
Study type: Field study
Sample: 4248 questionnaires, 56 schools
Duration: Cross-sectional
Age or developmental stage: 6th grade

Wang, C., Zhang, F., Wang, J., Doyle, J. K., Hancock, P. A., Mak, C. M., & Liu, S. (2021). How indoor environmental quality affects occupants' cognitive functions: A systematic review. *Building and Environment*, 193(September 2020), 107647. https://doi.org/10.1016/j.buildenv.2021.107647

This review analyses five different categories of Indoor Environmental Quality including IAQ, thermal environment, noise, lighting, non-visual lighting visual factors, lighting and related them with different aspects from cognition drawn from the literature. These aspects include attention, perception, memory, language function, higher order cognitive skills, and social cognition. The review points to the fact that the associations between indoor Environmental Quality factors and the five main categories of cognitive functioning have a large set of inconsistencies, uncertainties, and possible explanations. Issues related to age, gender, skill level, emotion, and personal attitudes in past events, could act as mediators, moderators, or confounders. The relationship between IEQ and cognition the existing literature does not have enough granular evidence to present a comprehensive understanding of the underlying mechanism. Also, different cognitive tests have been developed in isolated research communities so there is no consensus of a single mechanism for measuring cognition. The complexity of the relationship between IEQ, cognition, and causality needs multidisciplinary endeavors to developing protocol that permits the synthesis of the findings in this area.[67]

Publication type: Journal article
Study type: Literature review
Study type: Literature review
Sample: 66 studies selected

Young, B. N., Benka-Coker, W. O., Weller, Z. D., Oliver, S., Schaeffer, J. W., & Magzamen, S. (2021). How does absenteeism impact the link between school's indoor environmental quality and student performance? *Building and Environment*, 108053. https://doi.org/10.1016/j.buildenv.2021.108053

Young et al. studied how absenteeism acted as a mediator between IEQ and test scores in math and reading in the Transitional Colorado Assessment Program – TCAP, using the ORC (operations report card) of the school as an indicator of IEQ. The study used over 18000 test scores from grades 3rd to 9th, in 47 schools in Colorado since 2016. The ORC was measured for 5 building conditions. Absenteeism was found to not be a mediator, but an important

variable for test performance. Absenteeism had no effect in the association between exposures and test performance. Also, there was no association between IAQ and test performance. On the other hand, other variables such as socioeconomic status, free lunch program, and race/ ethnicity were key influencers of test performance. The study works with a large dataset, but the absenteeism measure they use can't be directly related to health, as this measure wasn't available for their study. [68]

Publication type: Journal article
Study type: Secondary analysis
Sample: Over 18000 test scores in 47 schools
Age or developmental stage: Grades 3rd to 9th

Catalina, T., & Iordache, V. (2012). IEQ assessment on schools in the design stage. *Building and Environment*, 49(1), 129–140. https://doi.org/10.1016/j.buildenv.2011.09.014

Catalina and Iordache address how schools are affected by IEQ and by making an IEQ index model to help builders and engineers as they are designing buildings. There was also a focus on building's energy consumption compared to indoor environmental conditions. The methods involved in this research and case study were using a regression models approach to understand the dependent variable and its relation to multiple independent variables. This would then measure visual comfort, acoustic comfort, indoor air quality, climate, glazing surface, and distribution, building shape, average building insulation value, fresh air, wall/window sound, and outdoor noise level. The IEQ was measured with a rating based on parameters. The case study focused on a single school that involved prediction models analysis and IEQ assessment to understand how the indoor environmental quality in schools could be affected by design. The study concluded that the models proposed in the text can be viewed as accurate for rehabilitation or building design to understand energy consumption and IEQ. [69]

Publication type: Journal article
Study type: Research Paper and Case Study
Sample: 1 Building
Duration: Longitudinal
Age or developmental stage: School Age

De Giuli, V., Da Pos, O., & De Carli, M. (2012). Indoor environmental quality and pupil perception in Italian primary schools. *Building and Environment*, 56, 335–345. https://doi.org/10.1016/j.buildenv.2012.03.024

De Giuli, Da Pos, and De Carli address how students perceive their environment at school, specifically how the indoor environmental quality is perceived and affects students. The methods involved in this study are seven primary schools close to Venice, Italy. The measurements involved spot measurements that were taken in 28 classrooms that were not airconditioned, during the springtime. 614 students participated in the study, ages 9 to 11, and they were given a questionnaire that measured their perception of their indoor environmental conditions. There were nonparametric statistical tests given to understand the possible effect of gender. Physical measurements were also measured as well as discomfort measurements. The study found

that there were high CO2 concentration levels that meant there was an insufficient change of air with open windows. The study also found that there was insufficient lighting and disturbances due to illuminance. The study found that students perceived their environment as having too warm thermal conditions, along with poor noise and indoor air quality but also satisfaction and therefore productivity and learning. This research collects some pictures of indoor environmental conditions taken in seven primary schools near Venice (Italy, North-East).[70]

Publication type: Journal article
Study type: Case Study
Sample: 614 students, 28 classrooms
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Primary, 9 to 11 Years Old

Thermal Comfort

Almeida, R. M. S. F., Ramos, N. M. M., & De Freitas, V. P. (2016). Thermal comfort models and pupils' perception in free-running school buildings of a mild climate country. *Energy and Buildings*, *111*, 64–75. https://doi.org/10.1016/j.enbuild.2015.09.066

This paper presents an assessment of the thermal comfort of children at different stages of development. The study consists of 32 measurements in 10 educational spaces in Portugal. They surveyed classrooms from students in different developmental stages, including from kindergarten to college, and gathered 490 questionnaires. They assessed thermal comfort according to PMV and the EN 15251 adaptive model. They found that the metabolic rate needed to be adjusted depending on the development stage of children. They found no perfect agreement between PMV and mean thermal sensation, and the PMV was found to be more restrictive. Educational buildings play a key role in creating a good social climate and conditions in which children and young people can develop. Several international studies have been conducted to evaluate students' performance and the factors that most influence it, including classrooms' thermal comfort. Yet, various revealed differences between pupils' perception and the results of thermal comfort models. The large majority of the thermal comfort studies in classrooms were performed in heated and mechanically ventilated spaces. In free-running spaces, occupants' expectations tend to be different and a lack of information was detected. In this research, data collected in 32 measurements in 10 educational spaces and 490 questionnaires were used to assess thermal comfort conditions in Portuguese educational buildings. Measurements were performed in classrooms and libraries and the sample included buildings from kindergarten to college. Global comfort was assessed by PMV index and according to EN 15251 adaptive model. In parallel, pupils' perception was collected through specific questionnaires adapted according to their ages. The answers allowed a detailed analysis regarding the definition of

the best methodology to quantify the adequate children's metabolic rate to be considered in the thermal comfort numerical analysis. It was found that when using the PMV analytical approach, metabolic rate must be adjusted and, according to the results, the best methodology is to use children's body surface area as correction factor. Generally, students felt comfortable and a large majority would maintain the indoor conditions unchanged. No perfect agreement was found between calculated PMV and the mean thermal sensation collected through questionnaires. Moreover, when comparing PMV index and EN 15251 model, PMV stands out as more restrictive.[71]

Publication type: Journal article
Study type: Field study
Sample: 490 questionnaires, 32 measurements in 10 educational spaces
Duration: Single point in time
Age or developmental stage: Kindergarten to college

de Dear, R., Xiong, J., Kim, J., & Cao, B. (2020). A review of adaptive thermal comfort research since 1998. *Energy and Buildings*, 214, 109893. https://doi.org/10.1016/j.enbuild.2020.109893

This paper reviews the last 21 years of adaptive comfort research. It examines the progress of adaptive comfort from the perspective of theory, standards, practice, building typologies, boundaries of the comfort zone, and comfort expectations. Regarding cognitive performance in children, they find that school students consistently prefer cooler temperatures than adults. It seems that students may be just "passive recipients" of their environment, as their teachers are usually in control of the windows, etc. They also discuss the inverted-U model vs. the extended-U model of cognitive performance, and state that the extended U-model (which allows for adaptability) has more empirical weight evidence, while the inverted U-model creates overcooling in buildings below 22°C. [72]

Publication type: Journal article,
Study type: Literature review

Haverinen-Shaughnessy, U., Turunen, M., Metsämuuronen, J., Palonen, J., Putus, T., Kurnitski, J., & Shaughnessy, R. J. (2012). Sixth Grade Pupils' Health and Performance and Indoor Environmental Quality in Finnish School Buildings. *British Journal of Educational Research*, *2*(1), 42–58.

This study aims at understanding the relationship between the health and academic performance of children in finish elementary schools. The study took one year to gather data and used a sample of 334 schools, collecting information from 6th grade students. It gathered multilevel data using data from the buildings collected from the Finnish Population Register Center, a questionnaire from school principals, on-site inspections, and environmental measurements from a subsample of schools, student self-reported health data, and learning outcomes from a standardized test in math. This paper concentrates on the two latter ones. The study found that those who had never experienced high indoor temperatures had 4% more correct answers than those who experienced them daily. Also, those who did not miss school due to respiratory infections had one point 1.1% more correct answers on

math. The study found other associations between math and headaches or difficulty concentrating, however the authors state that these associations need further study.[73]

Publication type: Journal article
Study type: Research Study
Sample: 334 schools, 4248 questionnaires from students
Duration: Cross-sectional, a year of data collection
Age or developmental stage: 6th grade

Jiang, J., Wang, D., Liu, Y., Xu, Y., & Liu, J. (2018). A study on pupils' learning performance and thermal comfort of primary schools in China. *Building and Environment*, 134(February), 102–113. https://doi.org/10.1016/j.buildenv.2018.02.036

This study analyzes pupil performance based on four aspects: attention, perception, comprehension, and deduction. Twelve-year-old students were put in groups and exposed to six different temperatures. They were told to assess thermal comfort, thermal sensation, sick building syndrome symptoms, and given different tasks to evaluate performance. The study looked at accuracy, response time and learning performance. They found that most students felt neutral at 15 °C, and that the influence of temperature on learning performance varied significantly and depended primarily on the task type. Thermal discomfort caused by high or low temperatures negatively influenced student learning performance. Optimum performance was reached at 14 °C. The relationship between temperature and pupil learning performance was found to be significantly cubic. The best learning performance was obtained when thermal sensations were between cool and slightly cool, in this case mean vote = -1.4. This finding is consistent with other studies that state that students prefer cooler temperatures than adults and aligns thermal comfort with student performance. [74]

Publication type: Journal article
Study type: Experimental study
Sample: 12 students
Duration: One hour a day for 6 days
Age or developmental stage: 12-year-old students

Jiang, H., Iandoli, M., Van Dessel, S., Liu, S., & Whitehill, J. (2019). Measuring students' thermal comfort and its impact on learning. *EDM 2019 - Proceedings of the 12th International Conference on Educational Data Mining, Edm, 89–98.*

In this paper Jiang et al. present an experiment where they assess the influence of temperature changes on learning performance. To do this they assigned 25 university students to different temperature conditions, with a total change of 5 °C (25 to 30 or 30 to 25). They asked participants to learn from 4 tutorial videos in 21-minute sessions and were tested afterwards. The total length of the experiment was of 84 minutes. For the experiment they used environmental sensors, body sensors, cameras, and infrared cameras, as well as thermal comfort surveys. An external observer rated the level of engagement of participants using frames of the videos. They found a "slightly inverted U-shape" relationship between thermal comfort sensations and

quiz scores (It shouldn't be too comfortable or not too comfortable). Also, they found a positive correlation between thermal comfort and sleepiness, and between learning and engagement. They found that changing the temperature by a few degrees affects students' self-reported TC. They concluded that TC could be predicted by either using the room temperature, or the facial temperature reading from an infrared camera. Otherwise, predicting thermal comfort from a normal camera alone is limited. [75]

Publication type: Journal article
Study type: Experimental study
Sample: number
Duration: Single point in time
Age or developmental stage: University students

Jiang, J., Wang, D., Liu, Y., Di, Y., & Liu, J. (2021). A holistic approach to the evaluation of the indoor temperature based on thermal comfort and learning performance. *Building and Environment*, *196*, 107803. https://doi.org/10.1016/j.buildenv.2021.107803

The study proposes a method for determining the temperature and design parameters considering the effects of thermal comfort and learning. They come up with temperatures that are lower than the standard and that consider both parameters. The field study they use as a basis was developed during the winter in rural China. To evaluate thermal comfort, they gathered 781 sets of field measurements, including 9 schools and 26 classrooms, as well as thermal comfort surveys from children ages 9 to 16. The questionnaires were developed 4 times a day at specific hours. To evaluate performance, they carried out a series of experiments in a controlled classroom environment in primary schools, where they exposed students to six temperature conditions from 10 °C to 20 °C. They performed cognitive tests evaluating children for attention, perception, comprehension, and deduction. Using statistical analyses and mathematical modeling, they found that the recommended temperatures ranged from 13 °C to 15 °C for optimal performance, considering that during the winter students are wearing heavy coats. They state that this finding may aid schools save energy. [76]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 781 sets of field measurements, 9 schools and 26 classrooms
Duration: Single point in time
Age or developmental stage: 9 to 16 years old

Korsavi, S. S., & Montazami, A. (2020). Children's thermal comfort and adaptive behaviours; UK primary schools during non-heating and heating seasons. Energy and Buildings, 214, 109857. https://doi.org/10.1016/j.enbuild.2020.109857

This paper studies children's thermal comfort votes in 32 naturally ventilated classrooms in primary schools in the UK, during non-heating and heating seasons. The authors gave 1390 questionnaires to 805 children, 9-11 years old. They gathered environmental measurements, thermal sensation votes and thermal preference votes. Their main finding suggests that children's thermal comfort is 1.9K and 2.8K lower than for adults in the non-heating and

heating seasons. [77]

Publication type: Journal article
Study type: Field study
Sample: 1390 questionnaires, 805 children
Duration: Longitudinal, one year of physical measurements, and questionnaires in two different seasons
Age or developmental stage: 9-11 years old

Korsavi, S. S., Montazami, A., & Mumovic, D. (2020). The impact of indoor environment quality (IEQ) on school children's overall comfort in the UK; a regression approach. *Building and Environment*, *185*(September), 107309. https://doi.org/10.1016/j.buildenv.2020.107309

This paper studies the influence of different aspects of individual environmental parameters on general comfort sensations. The authors used information from 32 naturally ventilated classrooms during non-heating and heating seasons, and gave 1390 questionnaires to 805 children, 9-11 years old. This paper presents the second part of a study developed by the authors in 2020. In this one, the focus is on the relationship between air sensation votes (ASV) and thermal comfort for overall comfort. They use regression models to determine their influence on thermal comfort. Their main finding is that: "To achieve acceptable comfortable votes and keep the probability of having uncomfortable votes below 10%, ASVs and operative temperature (Top) should be kept within these limits: [ASV = very fresh and Top = 19 – 27 °C], [ASV = fresh and Top = 19–24 °C], and [ASV = OK and Top = 19–22 °C]." They state that this study may help prioritize certain aspects of building design, by knowing which parameters influence comfort the most. [78]

Publication type: Journal article
Study type: Field study
Sample: 1390 questionnaires, 805 children
Duration: Longitudinal, one year of physical measurements, and questionnaires in two different seasons
Age or developmental stage: 9-11 years old

Kwok, A. G. Thermal comfort in naturally-ventilated and air-conditioned classrooms in the tropics. *UC Berkeley (1997).*

In this dissertation the author developed fieldwork in 6 schools in Hawaii in order to investigate thermal comfort in naturally-ventilated and air-conditioned classrooms in a tropical climate. A total of 3544 students and teachers distributed in 29 classrooms participated in the study. The author developed questionnaires, physical measurements and statistical analysis and found that the majority of classrooms didn't comply with the conditions recommended by the ASHRAE standard 55-1992, which was the version of the standard in force at the time. In addition, the study also revealed that regardless of being inside or outside the comfort zone, there was an 80% of acceptability among respondents in both naturally-ventilated and air-conditioned classrooms. Finally, the author suggests opportunities for energy conservation through wider comfort zones, as well as separate comfort standards. This study was one of the first studies on thermal comfort

in schools developed in the US. [79]

Publication type: Dissertation
Study type: Field study
Sample: 6 schools, 29 classrooms, 3544 students
Duration: Two seasons (Hot and cool)
Age or developmental stage: 13-19 years old

Kwok, A. G. & Chun, C. Thermal comfort in Japanese schools. *Sol. Energy* 74, 245–252 (2003).

In this paper the authors investigated the applicability of thermal comfort standards in Japanese schools and compared the thermal comfort conditions of naturally ventilated and air-conditioned classrooms. The researchers developed physical measurements and questionnaires in two schools during the late summer season to develop the evaluation. The study collected a total of 74 responses from students, from which approximately 60% came from naturally ventilated classrooms, and 40% came from air conditions classrooms. The study found that air-conditioned classrooms were inside the comfort zone, but respondents were often feeling slightly cool. On the other hand, naturally ventilated classrooms were 5.4 °F (3 °C) warmer than the air-conditioned classrooms. Nonetheless, respondents voted in the three middle categories of the ASHRAE comfort zone, nearing neutrality. Finally, they didn't find a correlation between neutral sensations and students thermal preference. [80]

Publication type: Journal Article
Study type: Field study
Sample: 2 schools, 74 students
Duration: One summer
Age or developmental stage: On average 15 years old

Liu, J., Kang, J., Li, Z., & Luo, H. (2021). Overall effects of temperature steps in hot summer on students' subjective perception, physiological response and learning performance. *Energy and Buildings*, 247, 111124. https://doi.org/10.1016/j.enbuild.2021.111124

In this paper authors investigate the overall effect of step temperature changes on student perception physiological response and learning performance. This is an experimental research where they tried for temperature step conditions on 16 participants: (S6: 34 °C-28 °C, S8: 34 °C-26 °C, S10: 34 °C-24 °C, S12: 34 °C-22 °C). The participants were in university students acclimated to the city of Wuhan, where the experiment was developed. Participants spent a total of 96 minutes in three different rooms experiencing the temperature steps. Physical measurements, physiological measurements and subjective perceptions were taken. They found that only 62.5% of students found 22 °C thermally acceptable. The preferred temperature of comfort was 26 °C. The physiological responses of students were dependent on the magnitude of the temperature steps. They found no significant differences in learning performance between the four conditions tested. the differences in performance were lower than 2% which may not have practical meaning for building management. The authors recommend setting indoor temperatures

between 24 °C and 28 °C.[81]

Publication type: Journal article
Study type: Experimental study
Sample: 16 participants
Duration: 96 minutes per exposure
Age or developmental stage: University students, 23 years old

Mishra, A. K., & Ramgopal, M. (2015). A comparison of student performance between conditioned and naturally ventilated classrooms. Building and Environment, 84, 181–188. https://doi.org/10.1016/j.buildenv.2014.11.008

In this study they compared the performance of the same 50 undergraduate students, in both naturally ventilated (NV) classrooms and air-conditioned (AC) classrooms over the course of two years. They assessed performance using the final grades of the students and found no statistically significant difference in the performance. They state that the ability to adapt can outweigh the environmental parameters that influence performance. They found that in NV classrooms that are well designed, students might be just as satisfied as in AC classrooms, so, their performance might be similar in both classroom types. [82]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 50 students
Duration: The span of one course
Age or developmental stage: Undergraduate

Park, R. J., Behrer, A. P., & Goodman, J. (2021). Learning is inhibited by heat exposure, both internationally and within the United States. Nature Human Behaviour, 5(1), 19–27. https://doi.org/10.1038/s41562-020-00959-9

Authors investigate the effect of heat on learning both internationally and in the US. For international students they developed statistical analysis using databases from the PISA test from 58 developed and developing countries between 2000 and 2015, measuring learning in math, reading and science. For the US they used the SEDA test, and considered ELA (English language and arts), and math scores from over 12000 US school districts. They found that hotter temperatures in years leading up to the PISA exam negatively impacted student performance. Each additional day above 26.7 °C (80 °F) during the 3 years preceding the test lowered the scores by 0.18% standard deviations. Cold days had statistically insignificant impacts for performance, and temperature had a greater impact in poorer countries and less in rich ones. In the US, they used district level and daily weather as units of observation. Schools in the south of the US typically performed worse than those in the northeast. Nonetheless, they mention that many other factors may affect this relationship. Like the international result, an additional day above 26.7 °C (80 °F) reduced achievement by 0.04 of a standard deviation. Heat on non-school days had no statistically significant impact on achievement. The impact on math scores was three times as large as the impact on ELA. Hot temperatures affected vulnerable, low-income communities, more than

higher income districts. Finally, they found that the effect of hot school days was larger for younger students (3rd to 5th grade) than to older students (6th to 8th grade). Despite these findings and apparent causal relationships, they recognize that heat exposure may not be the only mechanism at place to provide these results. [83]

Publication type: Journal article
Study type: Secondary analysis
Sample: PISA test from 58 countries, SEDA tests from over 12000 US school districts
Age or developmental stage: 15 to 19 year-olds and 3rd to 8th graders.

Rodríguez, C. M., Coronado, M. C. & Medina, J. M. Thermal comfort in educational buildings: The Classroom-Comfort-Data method applied to schools in Bogotá, Colombia. *Build. Environ.* 194, 107682 (2021).

In this paper the authors developed two case studies to assess thermal comfort in two naturally ventilated schools. They developed physical measurements of temperature, globe temperature, relative humidity and air speed in 20 classrooms over a month. They also applied three different sets of questionnaires to a total of 314 children ages 7 to 17, depending on the age group. They found that children seemed to prefer colder temperatures than those proposed by the adaptive standard. In addition, they found a significant relationship between self-reported negative cognitive effects of thermal discomfort and age, as well as a significant relationship between the perceived negative cognitive effects of thermal discomfort and overall thermal comfort votes. They found that other aspects such as behavior, agency to modify their immediate environment and the way the schools functioned also affected the results of their study. [84]

Publication type: Journal article
Study type: Field study
Sample: 2 schools, 20 classrooms, 314 students
Duration: One month
Age or developmental stage: 7 to 17 years old

Singh, M. K., Ooka, R., Rijal, H. B., Kumar, S., Kumar, A., & Mahapatra, S. (2019). Progress in thermal comfort studies in classrooms over last 50 years and way forward. *Energy & Buildings*, 149–174. https://doi.org/10.1016/j.enbuild.2019.01.051

This paper reviews and analyses 93 papers that study thermal comfort in classrooms for the last 50 years. The paper states that the classroom thermal environment has an important role in students' life as it influences performance and wellbeing. In general, it has been found that children prefer cooler temperatures than the ones in their thermal environments. They found that the operation mode of the classrooms had no effect on children behavior. They state that there is a need to develop different guidelines for students in different stages of their education. Curricula demands different activities, different learning approaches and systematic thinking, requiring increasing levels of concentration. With increasing awareness about energy efficiency in buildings and indoor environment quality, somehow more emphasis is being given to energy efficiency. The absence of any standard or reference

document relating to the design appropriate classrooms based on educational stages is worsening the situation. In this context, present study is done to find out the progress in classrooms based thermal comfort studies over last fifty years. Total 93 research articles selected from Scopus database were considered for this study. It was found that at each educational stage in the studied schools, students were highly unsatisfied with the prevailing indoor thermal environment and preferred cooler temperature than the existing indoor thermal environment. Primary school students were least sensitive to outdoor temperature changes. There are relatively few published articles published on thermal comfort in classrooms. Based on reported findings, no consistent temperature change was found necessary to record a shift of one thermal sensation vote by students at different educational stages in classroom. Identical behaviour was observed for classrooms operated under different operation modes. Moreover this study provides robust evidence that there is a need for separate set of different guidelines or standards for students of different ages in different stages of their education. This study also proposed adaptive comfort equations to estimate the indoor comfort temperature in classrooms at different educational stages.[85]

Publication type: Journal article
Study type: Literature review
Reviewed studies: 93 papers
Span: last 50 years

Teli, D., Jentsch, M. F., & James, P. A. B. (2012). Naturally ventilated classrooms: An assessment of existing comfort models for predicting the thermal sensation and preference of primary school children. *Energy and Buildings*, *53*, 166–182. https://doi.org/10.1016/j.enbuild.2012.06.022

This paper assesses the existing comfort model predictions against thermal sensation and thermal preference votes of children. The authors recorded a total of 1314 responses from children 7-11 in Hampshire, New England, outside of the heating season. They collected thermal sensation votes and thermal preference votes in naturally ventilated classrooms. They developed environmental monitoring and assessed the applicability of the adaptive comfort model from the standard EN-15251. The study found that children are more sensitive than adults to higher temperatures, with comfort temperatures being 2 °C to 4 °C lower than the PMV and the 15251 adaptive standard predictions mainly in offices. There is no assurance however that these models apply to children. This paper presents findings from thermal comfort surveys and measurements of indoor environmental variables in naturally ventilated classrooms in Hampshire, England. School children aged 7-11 were surveyed regarding their thermal sensation and preference in repeated survey runs outside the heating season, gathering about 1300 responses in total. The results were compared to predictions achieved with the two common approaches used in existing comfort standards, the heat balance and the adaptive comfort model.[86]

Publication type: Journal article
Study type: Field study
Sample: 230 students, 1314 responses
Duration: Cross-sectional, 12 days

Age or developmental stage: 7 to 11

Teli, D., Jentsch, M. F., & James, P. A. B. (2014). The role of a building's thermal properties on pupils' thermal comfort in junior school classrooms as determined in field studies. *Building and Environment*, 82, 640–654. https://doi.org/10.1016/j.buildenv.2014.10.005

The paper assesses whether building construction influences children thermal sensation. It develops a POE in a medium weight building to compare children thermal sensations to a previous study done in a lightweight building, where they found that children were more sensitive to higher temperatures than adults. They found that despite the building being cooler, the construction didn't influence children's thermal sensations, and the results were consistent with those of the previous study. Both surveys followed the same methodology, including thermal comfort questionnaires and measurements of indoor environmental variables. A total of 2990 responses were gathered. The buildings had an average difference in air temperature of 2.7°C during occupied hours in the period of investigation (June and July 2012).[87]

Publication type: Journal article
Study type: Field study
Sample: 2990 responses, 560 children
Duration: One month
Age or developmental stage: 7 to 11

Teli, D., Bourikas, L., James, P. A. B., & Bahaj, A. S. (2017). Thermal Performance Evaluation of School Buildings using a Children-based Adaptive Comfort Model. *Procedia Environmental Sciences*, *38*, 844–851. https://doi.org/10.1016/j.proenv.2017.03.170

This paper analyses thermal comfort in buildings considering that children are comfortable at lower temperatures and current EU criteria. Teli et al. developed an adaptive model for children based of 2800 thermal comfort responses for children, and then applied it to four case studies. They found that their model predicted overheating in 3 of four schools. The building with the best performance was the oldest one. The newer building kept a steady temperature but was consistently too high. They conclude that is a need to address the stage that children are at in their development to assess the appropriate thermal comfort model. Also, new buildings need to address the thermal needs of the months that are not part of the heating season in places like Southampton, UK, where this study took place. [88]

Publication type: Journal article
Study type: Field study and Theory development
Sample: 2800 responses, 43 classrooms, 4 schools
Duration: Three summer months for three years
Age or developmental stage: Not specified

Trebilcock, M., Soto-Muñoz, J., Yañez, M. & Figueroa-San Martin, R. The right to comfort: A field study on adaptive thermal comfort in free-running primary schools in Chile. *Build. Environ.* 114, 455–469 (2017).

This article presents a thermal comfort evaluation in 12 naturally ventilated schools in Santiago de Chile. The researchers gathered responses from 440 students that were 9–10-year-old during the winter and spring seasons. Students completed thermal comfort questionnaires for 3-4 days, several times per day, while the researchers gathered environmental data using physical measurements. Their result show that the comfort temperature of students was significantly lower than the temperature calculated for adults using the adaptive model. They found comfort temperature ranging from 58.5 °F to 60.8 °F (14.7 °C to 15.6 °C) during the winter and 72.5 °F to 73.6 °F (22.5 °C to 23.1 °C) in the spring. They also found that low SES students had a lower comfort temperature than higher SES students. [89]

Publication type: Journal article
Study type: Field study
Sample: 12 schools. 440 students
Duration: Winter and Spring seasons
Age or developmental stage: 9-10 years old

Zhang, F., de Dear, R., & Hancock, P. (2019). Effects of moderate thermal environments on cognitive performance: A multidisciplinary review. *Applied Energy*, 236 (November 2018), 760–777. https://doi.org/10.1016/j.apenergy.2018.12.005

In this extensive systematic literature review on the effects of thermal environments on cognitive performance they start by defining productivity as performance that helps achieve the goals of an organization. They mention that confounding factors that mediate the effects of the thermal environment on cognitive performance have to do with environment related (thermal stress, duration of exposures, thermal transients), task related (type of task, task complexity), and performer related factors (skill level, hydration status, thermal acclimatization), as well as interactions between the three. They also touch on the different methods to assess cognitive performance, from physiological tests to the construct validity/ sensitivity of the tests. Finally, they discuss the inverted U-model and the extended U-model of cognitive performance under thermal stress. They state that extended you model is better as it allows for adaptation, possible loads for reducing peak energy demands, and broadens the comfort zone for personal comfort systems. On the contrary, the inverted U-model only uses 22 °C as a parameter for optimal performance. Among their conclusions they state that cognitive performance should not be used as a proxy for the effect of the thermal environment on office productivity. [90]

Publication type: Journal article
Study type: Literature review

Zomorodian, Z. S., Tahsildoost, M., & Hafezi, M. (2016). Thermal comfort in educational buildings: A review article. In *Renewable and Sustainable Energy Reviews* (Vol. 59, pp. 895–906). Pergamon. https://doi.org/10.1016/j.rser.2016.01.033

This paper reviews field studies and methodologies used to develop them

in the last 50 years. They included studies developed in typical classrooms and organized them by climate zone, educational stage, and thermal comfort approach as main parameters. They mention that they couldn't do a meta-analysis as there was a limited number of studies and a wide variety of study conditions. They found that current TC standards are not appropriate to assess thermal comfort in classrooms. There is a need to assess micro-climate zones for thermal comfort studies since the existing results are not consistent. Also, the existing studies only look at specific points in time, and there is a need to develop studies during all the school year. They found that local discomfort evaluations could be useful to decrease dissatisfaction in classrooms. They state that ventilation is an important element for IAQ and comfort, as children prefer cooler environments. Overheating increases discomfort and reduces children performance, and energy conservation measures should be carefully applied to avoid hindering the performance of students. Finally, they state that temporal and spatial metrics could be useful for students staying in the same positions over long periods. [91]

Publication type: Journal article
Study type: Literature review

Indoor Air Quality

Angelon-Gaetz, K. A., Richardson, D. B., Marshall, S. W., & Hernandez, M. L. (2016). Exploration of the effects of classroom humidity levels on teachers' respiratory symptoms. International Archives of Occupational and Environmental Health, 89(5), 729–737. https://doi.org/10.1007/s00420-016-1111-0

This paper explores the relationship between teacher's health and classroom humidity. A total of 122 teachers reported daily respiratory symptoms, while data loggers measured relative humidity (RH) in 10 North Carolina Schools. The data was gathered in two separate campaigns. The first lasted two months and the second lasted four during the fall, winter, and spring seasons. The authors used poison regressions to assess the data and found that a prolonged exposure to low relative humidity was associated with modest, but not statistically significant increases in respiratory symptoms among teachers. Cold/allergy symptoms were not associated with high (RH>50%) or low RH (RH<30%) in the classroom. The potential relationship between classroom humidity and teachers' health has not been explored. Thus, we examined the relationship between classroom humidity levels and respiratory symptoms among North Carolina teachers.[92]

Publication type: Journal article
Study type: Field study
Sample: number
Duration: Longitudinal, two stages: 2 months and 4 months
Age or developmental stage: Teachers

Angelon-Gaetz, K. A., Richardson, D. B., Lipton, D. M., Marshall, S. W., Lamb, B., & Lofrese, T. (2015). The effects of building-related factors on classroom relative humidity among North Carolina schools participating in the "Free to Breathe, Free to Teach" study. *Indoor Air*, 25(6), 620–630. https://doi.org/10.1111/ina.12176

Angelon-Gaetz et al. aimed at quantifying the relationships between modifiable classroom factors and average daily RH below, within, or above levels recommended to improve school IAQ (30–50% or 30–60% RH). They developed a study looking at 134 North Carolina Classrooms in 22 buildings for 9066 classroom-days. Their findings point especially towards HVAC system performance in relation to humidity. They found that annual maintenance had higher odds of having RH above 60% than quarterly maintenance and found differences in RH human health. Classrooms with direct expansion (Dx) split system had a higher risk of RH<30%, compared to those with a chilled water system. They argue that this method doesn't provide any means to add moisture to the air if it becomes too dry. Classrooms in buildings between 11 and 40 years old had a higher risk of RH<30% compared to younger buildings, possibly due to the type of HVAC system. They point out that schools should make a risk management decision about whether to add humidifiers and estimates of days of low RH that may create adverse health effects.[93]

Publication type: Journal article
Study type: Field study
Sample: 134 North Carolina Classrooms in 22 buildings
Duration: 9066 classroom-days

Bakó-Biró, Z., Clements-Croome, D. J., Kochhar, N., Awbi, H. B., & Williams, M. J. (2012). Ventilation rates in schools and pupils' performance. *Building and Environment*, *48*(1), 215–223. https://doi.org/10.1016/j.buildenv.2011.08.018

This paper studies the relationship between ventilation rates and student performance in 8 primary schools. The authors performed 16 interventions in classrooms changing ventilation rates from 1 L/s to 8 L/s. The study lasted three weeks and was developed in two selected classrooms. Classrooms with increased ventilation, went from 5000 ppm to 1500 or 1000 ppm. 200 students participated in the study performing computerized tasks. Computerized performance of pupils increased in each task: choice reaction (2.2%), color word vigilance (2.7%), Picture memory (8%), word recognition (15%) with the intervention. The study concluded that higher ventilation rates increase attention and vigilance in pupils. On the contrary, low ventilation affects concentration and memory affecting teaching and learning. [94]

Publication type: Journal article
Study type: Quasi-experimental study
Duration: Three weeks
Age or developmental stage: 9-10 years

Bonilla, S., Kehl, S., Kwong, K. Y. C., Morphew, T., Kachru, R., & Jones, C. A. (2005). School absenteeism in children with asthma in a Los Angeles inner city school. *Journal of Pediatrics*, *147*(6), 802–806. https://doi.org/10.1016/j.jpeds.2005.06.041

This paper investigates the pattern of school absenteeism in asthmatic children within a Los Angeles inner city school. The authors used 513 surveys and attendance data comparison. They divided children in groups: High probability of asthma, low probability and known asthma. They found that children with asthma on average missed 2 more days of school. This finding was only significant in younger children. Also, they found that surveys were less accurate than school records on attendance, as both underestimation and overestimation of absenteeism rates occurred. [95]

Publication type: Journal article
Study type: Field study
Sample: 513 surveys
Duration: Cross-sectional
Age or developmental stage: Elementary school

Chithra, V. S., & Shiva Nagendra, S. M. (2018). A review of scientific evidence on indoor air of school building: Pollutants, sources, health effects and management. In *Asian Journal of Atmospheric Environment* (Vol. 12, Issue 2, pp. 87–108). Korean Society for Atmospheric Environment. https://doi.org/10.5572/ajae.2018.12.2.87

This is a review on IAQ in schools and related health effects on children. The study provides detailed explanation of all pollutants and touches upon indoor and outdoor pollutants. Indoor pollutant ranges vary in different parts of the world, depending on factors such as climate, type of ventilation, outdoor pollution, occupancy activities and building practices. Some of the findings of the review have to do with children's vulnerability for their developing stage. They point out that few studies have assessed various health outcomes with IEQ factors in schools. Most studies have looked at respiratory health, but other types of health outcomes such as nasal patency, lung function or rhinometry have been overlooked. It mentions 2 studies that looked at absenteeism as a measure of performance. They finalize by pointing to the need of high quality research to investigate health risks related to IAQ in school buildings. The first place for social activity and the most important indoor environment for children besides the home. Poor IAQ in classrooms can increase the chance of long-term and short-term health problems for students and staffs; affects productivity of teachers; and degrade the student learning environment and comfort levels. The primary objective of this paper is to review and summarize available scientific evidence on indoor air quality of schools and related health effects in children. It was found that the indoor air pollutant levels in school buildings varied over a wide range in different parts of the world depending on site characteristics, climatic conditions, outdoor pollution levels, occupant activities, ventilation type and building practices. Among the indoor air pollutants, particulate matter concentrations were found to be very high in many schools. Outdoor pollutant sources also play a major role in affecting the IAQ of the school building. Hence, scientific knowledge on sources of indoor pollutants, quantification of emissions, temporal and spatial dispersion of pollutants, toxicological properties, chemical and morphological characteristics of the pollutants and associated health risk among children in the school buildings are essential to evaluate

the adequacy and cost effectiveness of control strategies for mitigating the IAQ issues.[96]

Publication type: Journal article
Study type: Literature review

Daisey, J. M., Angell, W. J., & Apte, M. G. (2003). Indoor air quality, ventilation and health symptoms in schools: An analysis of existing information. *Indoor Air*, *13*(1), 53–64. https://doi.org/10.1034/j.1600-0668.2003.00153.x

This is a review on IAQ, ventilation, and building-related health problems in schools and identified commonly re- ported building-related health symptoms involving schools until 1999. They gathered data on ventilation rates, CO2, symptoms, pollutants. The review found that data on ventilation and CO2 data strongly suggest that ventilation is inadequate in many classrooms, which may lead to health symptoms. They found that low concentrations of VOC like HCHO - formaldehyde had been reported in the existing literature. These are known to lead to increased allergic sensitivity, chronic irritation, and cancer. Microbiological contaminants like allergens, fungi and bacteria were found in the literature as well. Finally, the review found that asthma and sick building syndrome were commonly reported.[97]

Publication type: Journal Article
Study type: Literature review
Sample: 300 peer-reviewed articles

Diette, G. B., Markson, L., Skinner, E. A., Nguyen, T. T. H., Algatt-Bergstrom, P., & Wu, A. W. (2000). Nocturnal asthma in children affects school attendance, school performance, and parents' work attendance. *Archives of Pediatrics and Adolescent Medicine*, *154*(9), 923–928. https://doi.org/10.1001/archpedi.154.9.923

This study seeks to determine if school absenteeism and school performance in children and work absenteeism in their parents are associated with awakenings from asthma at night. The authors developed a cross-sectional survey during the winter of 1997 through 1998 with 438 parents of children with asthma 5-17 years old. The parents reported children's absenteeism, parent missed work, and asthma effects on schoolwork in the last four weeks. Using multivariate analysis, the study was able to determine that nighttime asthma awakenings may affect absenteeism and performance, as well as parent absence to work. Children with more awakenings had higher odds of having absences at school. [98]

Publication type: Journal article
Study type: Field study
Sample: 438 parents of children with asthma
Duration: Cross-sectional
Age or developmental stage: 5-17 years old

Eitland, E. S. (2020). The Assessment of Building Interventions on Student Health. ProQuest Dissertations and Theses, 112. https://search.proquest.com/dissertations-theses/assessment-building-interventions-on-student/docview/2459429706/se-2?accountid=41849

This dissertation contains three different studies looking at Indoor Environmental Quality in schools. It starts by examining the effectiveness of smart dynamic purifiers versus continuously running purification. Both types reduced VOCs significantly, with higher reductions from a continuous system. Dynamic purification could reduce PM 2.5 from window indoor sources, but continuous purification may reduce daily PM 2.5 and VOC concentrations better. The second study examines the association between chronic absenteeism in Massachusetts and building conditions. Schools with most disrepair were associated with minority and disadvantaged students, and higher absenteeism. Lastly, Eitland analyzed the association of LEED certification with student test performance. She found no association as future green certified schools were higher performing already, and currently certified schools didn't acquire all the IEQ credits available. Eitland notes that LEED certification is not a good marker of student performance. Green certified buildings may not have acquired they IEQ credits necessary to provide environments that foster learning. [99]

Publication type: Doctoral Dissertation
Study type: Field study and Secondary analysis
Sample: 1,379 schools
Duration: Cross-sectional
Age or developmental stage: K-12 school level

Fisk, W. J. (2017). The ventilation problem in schools: literature review. *Indoor Air*, 27(6), 1039–1051. https://doi.org/10.1111/ina.12403

This literature review concentrates in cross sectional studies ventilation studies with more than 20 classrooms. It looks at 3 parameters: Carbon dioxide concentration and ventilation rate, associations between ventilation rates with health and performance, and the influence of ventilation rates on energy use and costs, using only used peer reviewed journals. Its main findings include the fact that ventilation rates in classrooms usually do not meet the minimum ventilation rates specified in the standards. There is compelling evidence of an association of increased student performance with increased ventilation rates to as much as 15%. Studies that looked at nasal patency (nasal openness) and nasal inflammation found improvements with increased ventilation. Nonetheless, the evidence of improved performance is more compelling that the evidence of improved health. Overall, the evidence indicates that student absence decreases with increased ventilation rates, but the available data are limited. Finally, the review found that increasing the ventilation rates would have a capital cost of less than 0.1 % of education spending. Other findings mentioned include that there is enough evidence to state that schools cannot just rely on opening windows to provide for the minimum ventilation rates. In some studies, sensors have proven valuable to address this issue. The review found no systematic data to assess reasons for low ventilation rates in mechanically ventilated buildings. The author concludes that buildings and systems should be designed and operated to

provide ventilation even when there is no heating or cooling needed.[100]

Publication type: Journal article
Study type: Literature review
Sample: Cross sectional studies with more than 20 classrooms

Fisk, W. J., Chan, W. R., & Johnson, A. L. (2019). Does dampness and mold in schools affect health? Results of a meta-analysis. *Indoor Air*, *29*(6), 895–902. https://doi.org/10.1111/ina.12588

This metanalysis looks at studies relating respiratory health of school occupants with visible dampness and mold. They used PubMed and Google scholar to perform the searches. The authors included only relevant articles that included Odds Ratios or Confidence intervals. They analyzed 11 studies with cross-sectional study designs using random effect models. The meta-analysis includes data from studies performed with children and adults. The results show that cough and wheeze generate moderate increases in health risk. Other papers not included in the meta-analysis suggest that dampness and mold are associated with adverse health effects.[101]

Publication type: Journal article
Study type: Meta-analysis
Sample: 11 studies

Gehrt, D., Hafner, M., Hocking, L., Gkousis, E., Smith, P., & Pollard, J. (2019). *Poor indoor climate, its impact on child health, and the wider societal costs*. www.rand.org/giving/contribute

This report reviews and assesses information on the thermal , air quality, acoustical, and light environments of European Union houses and schools and their impact on children. They performed a Rapid Enquiry Assessment (REA) to start finding the information and followed it with a multivariate regression analysis. Finally, they did an estimation of health and educational burden and a macroeconomic modeling for the parameters that were possible. They found tangible economic benefits in improving the ventilation rates in schools. They also discussed the assumptions that dampness has a direct relation with mold, and mold causing absenteeism. They did not find a lot of evidence on light, noise, or radiation. They found associations between living in cold homes and respiratory diseases. They found that for the EU, "The macroeconomic costs associated with children's health to damp and mold can be estimated to be US$62 billion over the next 40 years." [102]

Publication type: Report
Study type: Rapid Enquiry Assessment and PRISMA
Papers: 66 fully reviewed

Haverinen-Shaughnessy, U., Shaughnessy, R. J., Cole, E. C., Toyinbo, O., & Moschandreas, D. J. (2015). An assessment of indoor environmental quality in schools and its association with health and performance. Building and Environment, 93(P1), 35–40. https://doi.org/10.1016/j.buildenv.2015.03.006

This study looks at the associations between different IEQ parameters (T, RH, CO2 and settled dust) and biological contamination (culturable bacteria), with student's performance, absenteeism, and health data during 2 academic years. During the first year they monitored IEQ in 70 schools. In the second year they only monitored 27 schools but added a cleaning protocol using Adenosine triphosphate (ATP) monitoring systems and contact agar (RODAC) plates to detect culturable bacteria. They also gathered student data on socioeconomic background, absenteeism, performance, and number of visits to school nurse from the school district. They found that IEQ parameters appeared to be important and potentially related to student health and performance. They devised a series of correlations and regressions to find statistically significant associations between variables. Ventilation rates and satisfactory performance in mathematics were related. Also, they found associations between ventilation rates and visits to nurses for respiratory symptoms and associations between culturable bacteria and nurse visits due to gastrointestinal symptoms. They didn't find any significant relations between IEQ parameters and absenteeism. [103]

Publication type: Journal article
Study type: Field study
Sample: 70 schools and 27 schools
Duration: two classrooms every week for two years
Age or developmental stage: 5th grade

Moonie, S., Sterling, D. A., Figgs, L. W., & Castro, M. (2008). The Relationship Between School Absence, Academic Performance, and Asthma Status.

This study investigates the relationships between absenteeism, presence of asthma, and asthma severity level with standardized test level performance in a predominantly African American urban school district. The study gathered information on 3812 students (8-17 years) who took the Missouri Assessment Program (MAP) standardized test during the 2002-2003 academic year. Data was only gathered from students in grades 3, 4, 7, 8, 10, and 11. The study found a significant inverse relationship between absenteeism and test level performance on the MAP $p<0.001$. No difference in test level achievement was found between those with and without asthma ($p = 0.12$). Those with persistent asthma were more likely to score below nearly proficient, than those with mild or intermittent asthma. [104]

Publication type: Journal article
Study type: Secondary analysis
Sample: 3812 students
Duration: Cross-sectional
Age or developmental stage: Students 8-17 years old from grades 3, 4, 7, 8, 10, and 11

Haverinen-Shaughnessy, U., & Shaughnessy, R. J. (2015). Effects of classroom ventilation rate and temperature on students' test scores. *PLoS ONE*, 10(8), e0136165. https://doi.org/10.1371/journal.pone.0136165

In this paper the authors study the relationship between classroom ventilation rate and temperature on academic achievement using a multilevel approach with mixed linear models. The study gathers information on 3109 students, 140 fifth grade classrooms, in 70 elementary schools in the SW US. All classrooms had HVAC. Data on socioeconomic status and standardized tests were collected as well. They found significant associations between math scores and ventilation rates. The association was stronger in the classrooms with higher ventilation rates. The association remained significant with previous test scores, resulting in less unexplained variability. Students mean mathematics scores increased by 0.5% per each L/s per person increase. Scores also increased per each 1°C decrease in temperature within the 20-25°C range. Similar but more variable results occurred with science scores. Nonetheless, they could not reject the alternative hypothesis that students' test scores may be affected by their classroom ventilation rate and temperature, but state that maintaining a comfortable temperature and ventilation rates may be beneficial for students. They state that further studies are needed to examine the causality of the relationships they observed.[105]

Publication type: Journal article
Study type: Field study
Sample: 3109 students, 140 fifth grade classrooms, in 70 elementary schools
Duration: Cross-sectional
Age or developmental stage: Elementary schools, in fifth grade classrooms

Marcotte, D. E. (2017). Something in the air? Air quality and children's educational outcomes. *Economics of Education Review*, *56*, 141–151. https://doi.org/10.1016/j.econedurev.2016.12.003

In this study the author explores the relationship between man-made pollutants and natural pollutants on the performance of children from early childhood stages. He differences between prolonged exposure to pollutants and immediate effects of health from exposure to high levels of pollutants. He uses data from the early childhood longitudinal surveys from the National Center for Education Statistics to assess the student outcomes. The database follows kids from kindergarten up to middle school and includes performance data on math and reading, as well as family and school characteristics data. To assess IAQ, the study uses information on the EPA on air quality, as well as pollen levels using information from the National Allergens Bureau. The study found that students scored 1 to 2 percent lower on math and reading on days with high levels of pollen or fine airborne particulate matter, and asthmatic students performed about 10% lower on days with high ozone levels. The study concludes that poor air quality in the early stages of life affects school readiness. [106]

Publication type: Journal article
Study type: Secondary analysis
Sample: 1450 records
Duration: The study used longitudinal data

Age or developmental stage: Kinder to middle school

Mendell, M. J., Eliseeva, E. A., Davies, M. M., Spears, M., Lobscheid, A., Fisk, W. J., & Apte, M. G. (2013). Association of classroom ventilation with reduced illness absence: A prospective study in California elementary schools. *Indoor Air*, *23*(6), 515–528. https://doi.org/10.1111/ina.12042

In this study they looked at the association between ventilation rates (VR) and student absenteeism. The paper presents a two-year project performed in 28 schools in three districts in California. They monitored CO2 in schools and collected information on student illness absence from each classroom. All school districts had median VR below 7.1 L/s, the California standard. They found significant reductions in illness absence ($p < 0.05$) through increased ventilation rates for each additional 1 l/s in the school districts that provided full sets of data. The authors state that assuming the associations they found as generalizable, increasing the current average VR they found (4L/s) to the state standard, school absence would decrease in the state by 3.4%. This would in turn "increase attendance-linked funding to schools by $33 million annually and increase costs by only $4 million." [107]

Publication type: Journal article
Study type: Field study
Sample: 28 schools
Duration: Longitudinal, two years of monitoring
Age or developmental stage: grades 3, 4 and 5

Shaughnessy, R. J., Haverinen-Shaughnessy, U., Nevalainen, A., & Moschandreas, D. (2006). A preliminary study on the association between ventilation rates in classrooms and student performance. *Indoor Air*, 16(6), 465–468. https://doi.org/10.1111/j.1600-0668.2006.00440.x

This paper assesses the relationship between poor IAQ and student performance. It uses CO2 levels as a surrogate for classroom ventilation and compares them with student performance on tests. The study recorded exposure periods of 4-5 hours in fifth grade classrooms of 54 elementary schools within a district of the USA and correlated them with student performance on math and reading skill tests. The study used statistical analysis and controlled for confounding factors. Significant associations were found between classroom level ventilation rate and test results in math. A modest association $p < 0.1$ was found between ventilation rates and test scores. The authors state that non-linear effects may need to be considered for a better representation of an association. There is limited data linking poor IAQ in the classrooms to student performance. Whereas, it is assumed that poor IAQ results in reduced attendance and learning potential, and subsequent poor student performance, validating this hypothesis presents a challenge in today's school environment. This study explores the association between student performance on standardized aptitude tests that are administered to students on a yearly basis, to classroom carbon dioxide (CO2).[108]

Publication type: Journal article
Study type: Field study
Sample: 54 elementary

Duration: Cross-sectional, 4-5 hours of exposure
Age or developmental stage: Fifth grade

Shendell, D. G., Prill, R., Fisk, W. J., Apte, M. G., Blake, D., & Faulkner, D. (2004). Associations between classroom CO2 concentrations and student attendance in Washington and Idaho. *Indoor Air*, *14*(5), 333–341. https://doi.org/10.1111/j.1600-0668.2004.00251.x

This paper explores the association of student absence with measures of indoor minus outdoor carbon dioxide concentration (dCO2). To develop the study, the authors gathered data from absence and dCO2 data from 409 traditional and 25 portable classrooms from 22 schools in Washington and Idaho. Only primary schools with K-5 and K-6 were selected. They measured CO2 and estimated a ventilation rate of 7.5 L/s, which is the minimum by code. The study found that 45% of classrooms had short term CO2 above 1000 ppm. Also, it found that dCO2 was significantly associated with the annual average daily attendance (ADA) and pre-visit ADA. The average attendance decrease was correlated with CO2 over 1000 ppm. Yearly attendance was 2% higher in traditional classrooms when compared to portable classrooms ($p < 0.01$). Similarly, yearly decrease in absence was 2.5% higher in traditional classrooms ($p < 0.01$). [109]

Publication type: Journal article
Study type: Field study
Sample: 409 traditional and 25 portable classrooms from 22 schools
Duration: Cross-sectional
Age or developmental stage: Primary schools with K-5 and K-6

Takaoka, M., Suzuki, K., & Norbäck, D. (2017). *Current asthma, respiratory symptoms and airway infections among students in relation to the school and home environment in Japan*. https://doi.org/10.1080/02770903.2016.1255957

This paper investigates the associations between the school and home environment and current asthma, respiratory symptoms, and airway infections among Japanese students. The study was developed with 1048 Japanese students 12–15 from 4 schools. The researchers developed questionnaires and environmental measurements of temperature, relative air humidity (RH) and student density (students/m2 floor area), dust was collected from floors. They found that high RH, high student density and cat allergens at schools were associated with infections. In the home environment, paint, odors, new materials, cats as pets, windowpane condensation and dampness were associated with increased risk of infection. They state that the presence of cats and dogs at home can be protective. [110]

Publication type: Journal article
Study type: Field study
Sample: 1048 Japanese studentss
Duration: Cross-sectional
Age or developmental stage: 12-15 years

Toftum, J., Kjeldsen, B. U., Wargocki, P., Menå, H. R., Hansen, E. M. N., & Clausen, G. (2015). Association between classroom ventilation mode and learning outcome in Danish schools. *Building and Environment*, *92*, 494–503. https://doi.org/10.1016/j.buildenv.2015.05.017

This paper evaluates the effects of ventilation mode and other classroom characteristics with children performance. It presents a cross sectional study based on existing information on Danish test scores for the 2009-2010 years. The authors collected information on ventilation schemes and other classroom characteristics in two separate campaigns. During the first one, they gave equipment to the children in 311 Danish elementary schools and performed measurements in 1 to 16 classrooms in each school and got a total of 732 classroom measurements. During the second campaign they collected information of 88 classrooms in 88 schools. They measured CO2, air temperature and mold. Information on mold is not included in this paper. They found that reduced ventilation affects pupils' performance. Other aspects such as construction/renovation year, or occupancy didn't influence performance. Classrooms with regulated mechanical ventilation had a better performance than classrooms with unregulated natural ventilation. [111]

Publication type: Journal article
Study type: Field study
Sample: 389 Danish elementary schools, measurements in 1 to 16 classrooms per school
Duration: Cross-sectional, one month (phase 1) and 17 days (phase 2)
Age or developmental stage: 2nd through 8th grade

Toyinbo, O., Shaughnessy, R., Turunen, M., Putus, T., Metsämuuronen, J., Kurnitski, J., & Haverinen-Shaughnessy, U. (2016). Building characteristics, indoor environmental quality, and mathematics achievement in Finnish elementary schools. *Building and Environment*, *104*, 114–121. https://doi.org/10.1016/j.buildenv.2016.04.030

This paper studies indoor environmental quality (IEQ) in elementary school buildings and its association with students' learning outcomes. The study includes measurements of ventilation rates and temperatures in 108 classrooms, from 60 schools in 2007. The sample included data on health and school climate from 4248 students and 1154 school principals. They used test scores from a national test to assess performance. The study found associations between low math scores and ventilation rates below the standards. Also, it found that ventilation is associated with thermal comfort and learning outcomes. The study states that ventilation requires maintenance and adjustment to accommodate for a changing number of students. Upgrades to HVAC were correlated with airflow measurement, ventilation rate per student, and per area and per mean temperature. Ventilation rates were also correlated with the number of students in a classroom, and the mean temperature. The study found that only schools with mechanical supply and exhaust ventilation met the standard of 6 L/s per person. [112]

Publication type: Journal article
Study type: Field study
Sample: 4248 students and 1154 school principals
Duration: Cross-sectional

Age or developmental stage: sixth grade students

Van Gent, R., Van Essen, L. E. M., Rovers, M. M., Kimpen, J. L. L., Van Der Ent, C. K., & De Meer, G. (2007). Quality of life in children with undiagnosed and diagnosed asthma. *European Journal of Pediatrics*, *166*(8), 843–848. https://doi.org/10.1007/s00431-006-0358-y

This study investigated the impact of undiagnosed asthma in children's quality of life. The study gathered data from 1,614 children, 7-10 years in 41 schools in the Netherlands. Children and parents completed Paediatric Asthma Quality of Life Questionnaires, and children were given a lung function testing with assessment of reversibility of use of salbutamol, to assess for asthma or undiagnosed asthma. The study found significant evidence that children with asthma presented lower quality of life based on Paediatric Asthma Quality of Life Questionnaires from parents and children ($p<0.05$). In addition, children with asthma reported higher school absenteeism ($p<0.05$), and children with diagnosed asthma had higher absenteeism than those with undiagnosed asthma ($p<0.05$). [113]

Publication type: Journal article
Study type: Field study
Sample: 1,614 children in 41 schools
Duration: Cross-sectional
Age or developmental stage: 7-10 years old

Wargocki, P., & Wyon, D. (2007). The Effects of Outdoor Air Supply Rate and Supply Air Filter ... 13(2), 165–192.

In this paper they assess the effects of ventilation on children performance. They used a blind crossover design with repeated measures of two classes 10 to 12 years old and performed interventions in conditions for a week at a time. They collected data using questionnaires and environmental measurements, and the children developed language and numerical tests. The study found a significant effect of ventilation rate in 70% of all the statistical tests performed for an effect on work rate. There were no significant effects on errors. Children reported feeling fresher air when the outdoor air supply was increased from 3 to 8.5 L/s. CO2 concentrations decreased from 1300 to 900 ppm, which acts as a marker of bioeffluent concentrations. They couldn't assess the effects of filters. [114]

Publication type: Journal article
Study type: Experimental study
Sample: 23 students per classroom, 2 classrooms
Duration: Blind crossover design, interventions 1 week at a time, seven exercises
Age or developmental stage: 10 to 12 years old

Twardella, D., Matzen, W., Lahrz, T., Burghardt, R., Spegel, H., Hendrowarsito, L., Frenzel, A. C., & Fromme, H. (2012). Effect of classroom air quality on students' concentration: results of a cluster-randomized cross-over experimental study. *Indoor Air,* 22(5), 378–387. https://doi-org.libproxy.uoregon.edu/10.1111/j.1600-0668.2012.00774.x

Authors address how the indoor air quality of classrooms affects the concentration levels of students. The methods involved in this cross-over experimental study were 20 classrooms of 3rd and 4th graders and it addressed the CO2 levels in the classroom compared with concentration levels. The study measured the levels of carbon dioxide (CO2) and the concentration performance (CP) of students. The study was a cross-over cluster-randomized experimental study and the classrooms had mechanical ventilation systems. The study also measured two days in one week and then a CP test was conducted with the numbers of characters processed and the number of errors collected. The cross-over experimental study found that there was no significant effect on the total number of characters processed or concentration performance. The study also found that the total number of errors was significantly increased in the worse conditions compared to the better conditions. The study found that CO2 levels affect the concentration performance of students as they increase. [115]

Publication type: Journal article
Study type: Cross-over Experimental Study
Sample: 20 Classrooms
Duration: Crossover design, Longitudinal, 2 times in a week for each classroom
Age or developmental stage: 3rd and 4th Grade

Velux Group, Rand Europe, Hafner, M. & Christoffersen, J. *Healthy Homes Barometer 2019 Growing up in (un)healthy buildings*. (2019).

This report presents the consequences of living in unhealthy homes for European children. Among the risk factors the report mentions are dampness, darkness, cold temperatures and excess noise. The report states that the consequences of living in unhealthy homes also translates to schools as better IAQ can increase performance, increase speed in solving tasks, improve attention and concentration and reduce absenteeism. The report states that each year European children miss 1.7 million school days due to unhealthy buildings. Schools can suffer from the same IEQ risks as homes. The report states that European classrooms often have lower ventilation rates than what is recommended by the European guidelines and present a chart where they calculate that European children ages 5 to 15 miss 181 school days per year due to indoor mold and dampness. [116]

Publication type: Report
Study type: Review

The Center for Green Schools. *Indoor Air Quality Fact Sheets*. (2021).

This series of fact sheets provide basic information about ventilation in schools, in particular in the context of Covid-19. They present the differences between mechanical and natural ventilation, as well as different kinds of mechanical ventilation that may be present in schools. The sheets present

and describe the benefits of technologies such as germicidal ultraviolet, in-room air cleaners, and HVAC filtration for schools, giving examples and best practices. Among these, they mention that schools should aim for 6 air changes per hour in a typical 1000 ft classroom. This efficiency rate can be accomplished through adding the efficiencies of all the existing systems in the space. The fact sheets present comparisons of different scenarios to achieve this goal. [117]

Publication type: Fact sheets
Study type: Guidelines

Microbes / COVID-19

Alsmo, T., & Holmberg, S. (2007). Sick buildings or not: Indoor air quality and health problems in schools. *Indoor and Built Environment*, 16(6), 548–555. https://doi.org/10.1177/1420326X07084414

In this study they aimed at unveiling factors contributing to health problems in Swedish schools related to IAQ. Poor IAQ has been linked with nonspecific health-effects symptoms that disappear shortly after they leave the building, as well as with specific building-related health effects that cause well-known health problems, cancerous, contaminant and irritant materials. This study looks at the latter. They developed measurements of total airborne particles and microbiological measurements of bacteria and fungi in 18 Swedish schools. The measurements were made with an air sampler and petri dishes with damp agar. They compared indoor values with outdoor values and found differences in the levels of bacteria. Fungi levels were similar. Indoor particles were way higher than outdoor particles. The humidity levels found were not in the fungi growth level (67%). Also, the values measured in the school were compared with values in a conventional apartment, before and after cleaning or removing particles. The values after removal were smaller. One important inference they made is that IAQ depends on the activity performed in a room and the furnishings and materials as they may prevent from cleaning the space adequately. [118]

Publication type: Journal article
Study type: Field study
Sample: 18 schools
Duration: Cross-sectional, Single point in time

Andualem, Z., Gizaw, Z., Bogale, L., & Dagne, H. (2019). Indoor bacterial load and its correlation to physical indoor air quality parameters in public primary schools. *Multidisciplinary Respiratory Medicine*, 14(1). https://doi.org/10.1186/s40248-018-0167-y

In this study they aimed at estimating bacteria load in the environment to determine the health hazard this poses in schools. They studied 51 randomly selected naturally ventilated classrooms in eight public primary

schools in Gondar city (Ethiopia) and used passive air sampling settling plates exposing a Petri dish of blood Agar media for an hour. They used a person correlation matrix to assess the correlation between bacterial load and physical parameters. Bacteria load correlations varied in the morning and the afternoon. In the morning relative humidity, PM 2.5 and PM 10 were significantly correlated with bacterial load ($p < 0.05$). In the afternoon relative humidity and temperature were significantly correlated with bacterial load ($p < 0.05$). They found that moderate to strong humidity was negatively correlated with total airborne bacteria both in the afternoon and morning. Nonetheless the relative humidity only ranged from 14 to 62%. This finding was not consistent with what they expected from previous studies. All other correlations with bacterial load were positive. [119]

Publication type: Journal article
Study type: Field study
Sample: 51 naturally ventilated classrooms
Duration: Cross-sectional, Single point in time, one hour of collection

Awada, M., Becerik-Gerber, B., Hoque, S., O'Neill, Z., Pedrielli, G., Wen, J., & Wu, T. (2021). Ten questions concerning occupant health in buildings during normal operations and extreme events including the COVID-19 pandemic. *Building and Environment*, *188*, 107480. https://doi.org/10.1016/j.buildenv.2020.107480

Authors ask 10 questions on how IEQ affects the health of the occupants in buildings. Questions address different aspects of buildings that affect human health and then concentrate on how the COVID pandemic has taught us lessons about health in buildings. Regarding schools they touch upon how children are one of the most vulnerable populations exposed to hazardous pollutants, respiratory symptoms, and asthma. They frame the idea of healthy buildings, as a tridimensional concept, which includes the physical, social, and mental dimensions. They consider the importance of specific topics related to healthy buildings such as building and health justice, the costs of healthy buildings, the use of modern technologies, and the need for a framework to understand and assess what a healthy buildings is. [120]

Publication type: Journal article
Study type: Literature review, Theory development

Johns Hopkins. (2021). *School Ventilation: A Vital Tool to Reduce COVID-19 Spread.* Authors (Issue May).

This report reviews the existing evidence on COVID-19 risk of transmission and makes recommendations considering school ventilation. In the report, they demonstrate that ventilation investments can be cost-effective, and better than deep cleaning as a measure to prevent COVID-19. To develop the report, the authors performed 32 interviews with experts in engineering, education policy and communications. They also developed a literature review and a webinar featuring experts in IAQ engineering. Their recommendations include investing in healthy air now to outlast the pandemic. To do this, they mention actions such as improving ventilation by bringing in as much as outdoor air as the HVAC system allows, using HEPA filters in classrooms and

common spaces, using only proven technologies like filters and ultraviolet germicidal, stopping enhanced cleaning, installing mechanical ventilation where they don't have it, and upgrading the ne they have. [121]

Publication type: Report
Sample: 32 interviews

de Klerk, E. D., & Palmer, J. M. (2021). Resetting education priorities during COVID-19: Towards equitable learning opportunities through inclusion and equity. *Perspectives in Education, 39(1), 12–28.* https://doi.org/10.18820/2519593X/pie.v39.i1.2

The researchers aim to determine the impacts of the Covid-19 pandemic on principals' perceptions of learning pedagogies, the effects on student learning from having to stay away from crowded indoor spaces, and possible courses of action that can be taken to better prepare for future scenarios. The researchers conducted semi-structured email interviews with five principals at rural schools in the Northern Cape province of South Africa to understand their refocused commitment given the context of the pandemic. The overarching theme of the interviews was that the pandemic laid bare the systemic inequalities that had already existed in the region; many of these rural schools did not have the funding or technology to offer online classes like many wealthier school districts had. The principals redoubled their commitment to inclusion and ending discrimination, and to finding solutions for a post-Covid world. Despite the deepening of racial and socioeconomic divides as a result of the pandemic, some principals voiced optimism that by bringing the inequalities more to light, more people would be spurred to action in fixing the issues. COVID-19 has affected the most deprived communities the hardest and exposed many systemic inequalities, leaving nations vulnerable and destitute. The need for quality education, while heeding to international mandates, including enacting the sustainable development goals (SDG).[122]

Publication type: Journal article, Commentary, Report, Book, Doctoral Dissertation
Study type: Research study
Sample: 5 principals
Duration: Single point in time

Perkins & Will. (n.d.). *K12 Roadmap for Return K-12 Education*. Retrieved May 24, 2021, from https://k12roadmap.perkinswill.com/

This website provides a guide to go back to schools safely, looking at strategies for health that include multiple dimensions. It is comprised of different sets of handbooks that contain different dimensions of health in schools. Some of the topics included are: IAQ, des-densification, physical education, areas of intervention, capacity guidelines, food security, reducing cross-contamination, equity and access, cleaning and disinfecting, personal protective equipment or PPE, and social and emotional learning. This website doesn't present findings as a regular paper, but it does have some recommendations based on previous research. [123]

Publication type: Report
Study type: Guidelines

Lessler, J., Grabowski, M. K., Grantz, K. H., Badillo-Goicoechea, E., Metcalf, J. C. E., Lupton-Smith, C., Azman, A. S., & Stuart, E. A. (2021). Household COVID-19 risk and in-person schooling. *Science, 372(6546), 1092–1097.* https://doi.org/10.1126/science.abh2939

This paper presents the results from a massive online survey in the United States on Covid-19 and in-person schooling, looking at the risks posed by in-person schooling to individuals and community members. The paper explores covid self-reported symptoms and their relation to in-person schooling and a multiplicity of mitigation strategies developed by schools. The study found a clear association between the risk of Covid-19 for adult household members and in-person schooling. Nonetheless, they also found that this association disappeared when more than seven mitigation strategies were reported, implying that mitigation strategies in schools tend to work. Still, the study warns that this association may not be causal, as there are many unaccounted factors and limitations in the survey. [124]

Publication type: Journal article
Study type: Secondary analysis

Abrams, E. M., Shaker, M., & Greenhawt, M. (2021). School Attendance, Asthma Risk, and COVID-19 in Children. *Journal of Allergy and Clinical Immunology: In Practice*, 9(6), 2145–2150. https://doi.org/10.1016/j.jaip.2021.03.006

In this paper the authors explore the risks of in-person schooling during the pandemic for children who suffer from asthma and allergies. The study reviews the current evidence and finds that there isn't evidence that children with asthma are at an increased risk of suffering from covid 19 morbidity or mortality, compared with children that don't have this disease. Nonetheless, they found a discrepancy between the perceived risk and the actual risk for asthmatic children. According to the authors, this difference is due to how the topic has been portrayed by the media, little guidance in transitioning asthmatic children to in person schooling, and regional and local differences in school reopening. They finalize by reinforcing the idea that communication is key to narrow the gap between actual and perceived risk. [125]

Publication type: Journal article
Study type: Literature review

Allen, J., Spengler, J., Jones, E., & Cedeno-Laurent, J. (2020). *5-step guide to checking ventilation rates in classrooms.* www.ForHealth.org

This document presents guidelines and best practices to check ventilation rates in schools. It presents a step-by-step guide including calculations, equipment, and resources to develop this kind of measurement. It is meant to be a short, informative easy-to-use document, not a research document.[126]

Publication type: Report
Study type: Guidelines

ASHRAE. (2020). ASHRAE Epidemic Task Force. www.ashrae.org/covid19

This resource provides up-to date information from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) including guides, core recommendations and FAQ regarding Covid-19 in different settings. It also includes one-page guidance papers, among which are guidelines for reopening schools, put out in August of 2020. The guidelines include inspection and maintenance of HVAC systems, ventilation, Filtration, Air cleaning, Energy use considerations and water system precautions. The website is an excellent resource as it is constantly being updated with the most current information. [127]

Publication type: Report / Website
Study type: Guidelines

Dietz, L., Horve, P. F., Coil, D. A., Fretz, M., Eisen, J. A., Van, K., & Wymelenberg, D. (2020). 2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations To Reduce Transmission. *mSystems*. https://doi.org/10.1128/mSystems.00245-20

In this article the authors present a set of considerations for the Built Environment to control the spread of the Covid-19 virus. This is one of the early articles that touched on the subject based on previous research in this area. The authors summarize existing research on the microbiology of the Built Environment and known information on coronaviruses to produce their considerations. Among the control and mitigation efforts they introduce are on the individual level, hand washing, social distancing, hand sanitizer and mask wearing. For the built environment they consider enhancing the HVAC systems and proper filter installation and maintenance. They also consider the possible role of increased humidity in the control of the virus, and its downsides, ventilation through windows, daylight and UV light as possible control measures. Finally, they consider the spatial configuration of buildings to encourage or discourage social interactions and virus transmission. [128]

Publication type: Journal article
Study type: Literature review

Centers for Disease Control and Prevention (CDC). (2021). *Guidance for COVID-19 Prevention in K-12 Schools | CDC.* https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/k-12-guidance.html

This resource presents up-to date information of the Centers for Disease Control about how to safely reopen K-12 schools. It provides a summary of the changes that have been happening since the pandemic started regarding the changes in guidelines for these facilities. It provides guidelines on how improve ventilation in schools as well as cleaning practices. [129]

Publication type: Report / Website
Study type: Guidelines

Fezi, B. A. (2020). Health engaged architecture in the context of COVID-19. *Journal of Green Building*, 15(2), 185–212. https://doi.org/10.3992/1943-4618.15.2.185

This paper uses a logical argumentation and historical approach to look at the covid pandemic and state how architecture and urbanism should respond. It does not create a comprehensive systematic review, but it touches on a multiplicity of ways to respond to the pandemic. It looks at the problem from a multiscale approach and proposes a multidimensional solution. It understands health not only from the medical scientific approach, but also from the social point of view. One of the important takeaways of the article is that ventilation, filtration and humidification are some of the key features of health engaged architecture in the interior space scale. In addition, the article mentions the object scale with hygiene, the people scale with distancing and isolation, as well as the the residential, working, shopping, transportation, and higher scale (neighborhood) implications for health in the pandemic.[130]

Publication type: Journal article
Study type: Literature review

Guo, M., Xu, P., Xiao, T., He, R., Dai, M., & Miller, S. L. (2021). Review and comparison of HVAC operation guidelines in different countries during the COVID-19 pandemic. *Building and Environment* (Vol. 187, p. 107368). Elsevier Ltd. https://doi.org/10.1016/j.buildenv.2020.107368

This paper presents a summary of the current guidelines (as of 2021) that have been put out by different associations related to heating, ventilation and air conditioning regarding ways to respond to the covid 19 pandemic. The paper found common recommendations among guidelines, especially regarding the importance of ventilation. Nonetheless, it also found some conflicting details having to do with the uncertainty of how the virus spreads and transmits in the built environment, including the recommended ventilation rates. [131]

Publication type: Journal article
Study type: Literature review

Hoang, A., Heming, A., ASHRAE, & The Center for Green Schools. (2021). *Preparation in the Pandemic : How Schools Implemented Air Quality Measures to Protect Occupants from COVID-19.*

This report presents the result of a survey developed by the Center for Green Schools with the support of ASHRAE to understand the degree of implementation of six IAQ strategies for ventilation and filtration to help reduce COVID-19 transmission at schools. They gathered information of 47 school districts and independent schools in 24 states. They found that the most common measure implemented by schools had to do with increasing outdoor air supply through the mechanical system, followed by improving filtration, and finally strategies related to windows and natural ventilation. [132]

Publication type: Report
Study type: Research study
Sample: 47 school districts and independent schools

Duration: Single point in time
Age or developmental stage: School level

Jones, E., Young, A., Clevenger, K., Salimifard, P., Wu, E., Lahaie Luna, M., Lahvis, M., Lang, J., Bliss, M., Azimi, P., Wilson, J. C.-L. C., & Allen, J. (2020). SCHOOLS FOR HEALTH Risk Reduction Strategies for Reopening Schools.

In this report from 2020 the authors address the measures that schools should take to reopen. They provide information on 5 different areas: healthy classrooms, healthy buildings, healthy activities, healthy schedules and healthy policies. Regarding healthy buildings they list the following measures: increase outdoor air ventilation, filter indoor air, supplement with portable air cleaners, verify ventilation and filtration performance, consider advanced air quality techniques, use Plexiglas as physical barrier, install no-contact infrastructure, keep surfaces clean, and focus on bathroom hygiene. They refer the reader towards the ASHRAE's Pandemic Task Force's plan for reopening schools and universities. [133]

Publication type: Report
Study type: Guidelines

Derby, M. M., & Pasch, R. M. (2017). Effects of Low Humidity on Health, Comfort & IEQ. *ASHRAE Journal, 59(9), 44–51.* https://go-gale-com.libproxy.uoregon.edu/ps/i.do?p=AONE&sw=w&issn=00012491&v=2.1&it=r&id=GALE%7CA525004012&sid=googleScholar&linkaccess=fulltext

This article presents a summary of the ASHRAE 1630 RP, a project developing a literature review on the health effects of low relative humidity. The article states that the project found that some effects of low RH, such as the impact of RH on dust mites and influenza, were well documented, whereas other effects are not well quantified. They also found that most studies with human subjects conducted tests at a limited number of humidity levels in part due to the costs associated with testing. Similarly, ventilation rates and exposure times to low humidity were confounding variables. The impacts of low humidity on comfort primarily focused on mucous membranes (i.e., eyes, skin, etc.). [134]

Publication type: Journal Article
Study type: Report summary

National Academies of Sciences, Engineering, and M. (2020). *Reopening K-12 Schools During the COVID-19 Pandemic.* National Academies Press. https://doi.org/10.17226/25858

In this report form 2020, the authors go over what the pandemic meant for schools before reopening, and then issue a set of considerations for reopening. They go over the existing guidelines for schools at that moment, as well as implementing and mitigation strategies to reduce transmission. The report makes recommendations regarding type decision to reopen, precautions to reopen, partnerships between school districts and public health officials, access to public health expertise, decision making coalitions, equity in reopening, financial burdens for schools, high priority mitigation

strategies and urgent research. [135]

Publication type: Report
Study type: Guidelines

World Health Organization. (2009). WHO Guidelines for Indoor Air Quality: Dampness and Mould. https://ebookcentral-proquest-com.libproxy.uoregon.edu/lib/uoregon/detail.action?pq-origsite=primo&docID=483469

This report from the World Health organization presents a review of the scientific evidence of health effects associated with building moisture and biological agents. Among its main findings are that the most important effects of moisture are increased prevalence of respiratory symptoms, allergies, asthma and immunological reactions. According to the report, the presence of many biological agents is due to dampness and inadequate ventilation. It states that excess moisture on almost all materials leads to growth of microorganisms such as mold, fungi and bacteria, which emit spores, cells and fragments of VOC. The report states that the agents that cause adverse health effects have not been identified conclusively, but an excess of agents including spores, cell fragments, allergens, mycotoxins, endotoxins, b-glucans and VOC form microbial growth, can be a potential health hazard. [136]

Publication type: Report
Study type: Guidelines

ASHRAE. (2016). ASHRAE Research Project Report 1630-RP. https://technologyportal.ashrae.org/Report/Detail/666

This report presents a literature review of scholarly articles that investigate the effects of low air humidity (RH<40%) on comfort, health, and indoor environmental quality (IEQ). The authors review 600 papers that looked at relative humidity (RH) below 40% and reported temperature. They found that low humidity has little impact in comfort, but increases dryness, eye irritation and static electricity as humidity decreases. Among the report's findings are that lower humidity increases influenza virus survival, while absolute humidity (AH)predicts influenza decrease in a wider range of temperature than RH. The report discovered inconclusive findings regarding the effects of humidity on IEQ and perceived health effects. Similarly, it found only a few studies used elderly, adolescent or children as study subjects. [137]

Publication type: Report
Study type: Literature review

Harvard TH. Chan School of Public Health. *COVID-19 Tools – Schools For Health*. https://schools.forhealth.org/covid-19-tools/.

In this website the Harvard TH. Chan School of Public Health presents a series of tools, relevant research and strategies to reopen schools during the Covid-19 pandemic. Among the tools the website presents are a portable air cleaner purification calculator and a maximum CO2 concentration calculator

that schools can use to improve their facilities during the pandemic and control the spread of the virus. In addition, the website contains other reports and news articles that document the changes that have been occurring during the pandemic. [138]

Publication type: Website
Study type: Guidelines and tools

Collaborative for High Performance Schools CHPS. *Ventilation for School Ventilation for COVID-19.* https://chps.net/sites/default/files/CHPS~COVID-19~Whitepaper~Sep2020.pdf *(2020).*

In this white paper, the Collaborative for High Performance Schools (CHPS) presents a series of ventilation strategies, including mechanical and natural ventilation for schools to improve ventilation in classrooms during the pandemic. The solutions they mention include evidence-based strategies for operations such as using MERV 13 filters, daily flushing, retro-commissioning, monitoring CO_2, opening doors and windows, using economizers, and preventive material inspections. They also include evidence-based design strategies for renovations and new buildings such as focusing on the health of the occupants, monitoring and displaying CO2, operable windows and connections to the outdoors, filtration, increasing ventilation rates, Dedicated Outside Air Systems, Demand Controlled Ventilation, reducing VOCs, and commissioning and functional checklists.[139]

Publication type: Report
Study type: Recommendations

Koep, T. H., Enders, F. T., Pierret, C., Ekker, S. C., Krageschmidt, D., Neff, K. L., Lipsitch, M., Shaman, J., & Huskins, W. C. (2013). Predictors of indoor absolute humidity and estimated effects on influenza virus survival in grade schools. *BMC Infectious Diseases, 13(1).* https://doi.org/10.1186/1471-2334-13-71

In this paper the authors investigate absolute humidity levels in classrooms during the winter to further study the effects of absolute humidity in influenza survival. They developed physical measurements using sensors to measure temperature, Relative humidity, and CO2 in two schools. They found that Absolute humidity (AH) changes indoor were strongly related to CO2 levels (related to human occupancy) and outdoor AH. They also found that humidifiers increased indoor AH by 4mb, which is sufficient to decrease projected 1 hour virus survival by 30%. They concluded that classroom humidification maybe a feasible approach to increase AH to levels that may decrease influenza virus transmission. [140]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 2 schools
Duration: 2 winters

Reiman, J. M., Das, B., Sindberg, G. M., Urban, M. D., Hammerlund, M. E. M., Lee, H. B., Spring, K. M., Lyman-Gingerich, J., Generous, A. R., Koep, T. H., Ewing, K., Lilja, P., Enders, F. T., Ekker, S. C., Huskins, W. C., Fadel, H. J., & Pierret, C. (2018). Humidity as a non-pharmaceutical intervention for influenza A. *PLoS ONE, 13(9).* https://doi.org/10.1371/journal.pone.0204337

This paper studies the relationship between seasonal humidity changes and influenza outbreaks. The authors developed an intervention in preschool classrooms to test the influenza virus survival and transmission in the air and fomites and compared it to a control classrooms. They collected 330samples in humidifies rooms and 320 samples in control rooms. They found a significant reduction in the total number of influenza A virus positive samples (air and fomite) and viral genome in the humidified rooms. The authors state that modifying humidity levels in classrooms may serve as a non-pharmaceutical intervention for influenza or other viral outbreaks in the future. [141]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 650 samples in classrooms
Duration: Single point in time

US Department of Education. ED COVID-19 HANDBOOK Strategies for Safely Re-opening Elementary and Secondary Schools. vol. 1 (2021).

This report contains the first volume presenting the set of strategies recommended by the CDC for Safe School Reopening. The report states that the CDC K-12 operational strategy includes a series of layered strategies such as correct mask wearing, physical distancing, handwashing and respiratory etiquette, cleaning, developing ventilation improvements and contact tracing. The report emphasizes the importance of the first two. The report also contains information on the thresholds determined by the CDC (low, moderate, substantial and high) to make the decision of opening schools. [142]

Publication type: Report
Study type: Guidelines

US Department of Education. *Ed COVID-19 handbook: Roadmap to reopening safely and meeting all students' needs. vol. 2* https://www2.ed.gov/documents/coronavirus/reopening-2.pdf (2021).

This is the second volume the CDC issued with guidelines for schools to reopen schools safely during the pandemic. This report concentrates on strategies to meet students' social, emotional, mental and physical health, as well as their academic needs. In addition, the report addresses the impact of COVID-19 on students' opportunity to learn and how to support staff and teachers' wellbeing. The report issues a variety of recommendations and concentrates on underserved students. [143]

Publication type: Report
Study type: Guidelines

Suarez-Lopez, J. R., Cairns, M. R., Sripada, K., Quiros-Alcala, L., Mielke, H. W., Eskenazi, B., Etzel, R. A., & Kordas, K. (2021). COVID-19 and children's health in the United States: Consideration of physical and social environments during the pandemic. *Environmental Research*, 197(December 2020). https://doi.org/10.1016/j.envres.2021.111160

This paper examines five topics that affect children development and health during the pandemic. These five topics are: exposures to environmental contaminants and the built environment, changes in food environments, limited access to educational resources, changes in social environments and family stressors, and finally, social justice and racism. Among built environment and environmental pollutant effects, the article mentions how by staying more time in unhealthy homes, children may be exposed to more allergens and indoor air pollutants. Similarly, the article touches on the fact that school closures and isolation measures may have impacted children's physical health through reducing the opportunities to play outside and develop physical activity. [144]

Publication type: Journal Article
Study type: Literature review

Morawska, L., Tang, J. W., Bahnfleth, W., Bluyssen, P. M., Boerstra, A., Buonanno, G., Cao, J., Dancer, S., Floto, A., Franchimon, F., Haworth, C., Hogeling, J., Isaxon, C., Jimenez, J. L., Kurnitski, J., Li, Y., Loomans, M., Marks, G., Marr, L. C., ~ Yao, M. (2020). How can airborne transmission of COVID-19 indoors be minimised? *Environment International* (Vol. 142, p. 105832). Elsevier Ltd. https://doi.org/10.1016/j.envint.2020.105832

In this paper from 2020 the authors argued that at the time there was sufficient evidence to support the idea that engineering controls, such as enhanced ventilation and filtration are a key element to limit the spread of the virus that caused the Covid-19 pandemic. They argued that public buildings such as hospitals, offices and schools can use engineering controls along with administrative and controls and personal protective equipment can use this kind of strategies to limit the spread of the virus. Among their recommendations are increasing outdoor air exchanges, eliminating air recirculation, supplementing ventilation with portable air cleaners, and avoiding overcrowding. [145]

Publication type: Journal Article
Study type: Literature review

Thermal Comfort and IAQ

Mendell, M. J., & Heath, G. A. (2005). Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air*, 15(1), 27–52. https://doi.org/10.1111/j.1600-0668.2004.00320.x

In this review from 2005, Mendell et al. studied the associations between HVAC system and building characteristics, and indoor pollutants and thermal

conditions with reduced attendance or impaired performance. They equaled attendance with performance stating that attendance might decrease performance directly. They found that the effects of IEQ on performance or attendance were likely to be mediated by thermal conditions and pollutants. HVAC, building characteristics influenced IEQ exposures in ways not fully understood, which may affect health, attendance, and performance. They did not find specific causal relationships on pollutants, thermal conditions and performance or attendance, as there was very little research available at the time. The review they had to include papers that referred to adults, to be able to get to conclusions, but research on this area has increased substantially ever since. This paper pointed out the lack of research on biological pollutants in scholarly writing at the time. Using a sound selection method, they were able to find that there was suggestive evidence on NO2 to decrease attendance, strongly suggestive evidence on the effects of pollutants on the performance of building occupants, suggestive, but non consistent evidence on low ventilation rates and reduced performance, and suggestive evidence on cleaning and health in adults. They summarized evidence of other individual links to health and performance or attendance, mostly related to respiratory illness and infections. [146]

Publication type: Journal article
Study type: Literature review
Age or developmental stage: Children and adults

Riham Jaber, A., Dejan, M., & Marcella, U. (2017). The Effect of Indoor Temperature and CO2 Levels on Cognitive Performance of Adult Females in a University Building in Saudi Arabia. *Energy Procedia*, 122, 451–456. https://doi.org/10.1016/j.egypro.2017.07.378

In this intervention study from Saudi Arabia, they examined the effects of temperature and CO2 levels (600, 1000, 1800 ppm) on vigilance and memory tasks. They gave performance tests and neurobehavioral cognitive tests to 499 female university students in two classrooms. They performed a continuous performance test CPT as representative of attention task and match to sample MTS as a working memory task. Also, they used the BARS battery – Behavioral assessment and research system for the cognitive performance assessment. They manipulated CO2 and Temperature for five weeks for each exposure, and controlled for light, sound, and participants' behavior, and controlled for other confounder variables. They found statistically significant effects between outcome conditions and 3 different temperatures (20, 23, 25 °C). Participants performed significantly faster at 25 and 23 °C relative to 20 °C. They found differences between of students from different ethnicity regarding learning and temperature preference. They found that AC at home influenced this preference. They also found significant deterioration of learning at 1000 to 1800 ppm compared to 600 ppm CO2. [147]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 499 female university students
Duration: Longitudinal. 5 weeks of exposures. Exposures were done always at the same time of the day.

Age or developmental stage: College age

Rivera, M. I. (2019). Indoor Environmental Quality in Chilean Classroom. September, 1–119. https://scholarsbank.uoregon.edu/xmlui/handle/1794/25257

This dissertation studied IAQ and thermal comfort in Chilean primary school classrooms. It studied differences in the physical conditions of public and private schools, the comfort expectations of students and teachers, and the differences in perceptions according to socioeconomic background. Nine free running classrooms were studied in Concepcion, Chile during the fall and winter of 2018. The study included 880 students 10 to 14, 80 teachers, who were surveyed twice a day. Other methods such as physical measurements, observations, interviews and statistical analyses were used too. The study found that the students were comfortable despite being outside the comfort zone and exposed to low IAQ. The study found a statistically significant difference in perceptions between students from different social backgrounds ($p<0.001$). [148]

Publication type: Doctoral Dissertation
Study type: Field study
Sample: Nine schools. Phase one: 28 classrooms, 888 students and 58 teachers, phase 2: 11 classrooms, 333 students and 23 teachers
Duration: Fall and winter
Age or developmental stage: 6th through 8th grade (10 to 14)

Wargocki, P., & Wyon, D. P. (2007). The effects of moderately raised classroom temperatures and classroom ventilation rate on the performance of schoolwork by children (RP-1257). *HVAC and R Research*, 13(2), 193–220. https://doi.org/10.1080/10789669.2007.10390951

This paper evaluates the effects of thermal and IAQ conditions on children schoolwork performance. Using a blind crossover quasi-experimental design with repeated measures, they evaluated the performance of 10 to 12 years old children during an intervention. The experiment consisted in the manipulation of the split cooling units in two school classrooms during the summer, by modifying the air temperature and the outdoor air supply rate. Classroom conditions were changed weekly and repeated one year apart. Student performance was assessed on the base of numerical and language-based tasks, and students' self-reported environmental perceptions and symptoms were recorded. Reducing the air temperature in classrooms from 25 °C to 20 °C improved the performance of schoolwork performed by children in numerical, language, concentration, and logical thinking tasks in terms of speed at the $p < 0.05$ level. Similarly, increasing outdoor air supply from 5 L/s to 10 L/s improved children performance in terms of speed. No effects were shown in language-based tasks. [149]

Publication type: Journal article
Study type: Experimental study
Sample: 23 students per classroom, 2 classrooms
Duration: Blind crossover design, interventions 1 week at a time, seven exercises
Age or developmental stage: 10 to 12 years old

Wargocki, P., & Wyon, D. P. (2013). Providing better thermal and air quality conditions in school classrooms would be cost-effective. *Building and Environment*, *59*, 581–589. https://doi.org/10.1016/j.buildenv.2012.10.007

Authors review and summarize seven field studies they developed on how classroom conditions affect children's schoolwork performance, including only mechanically ventilated schools. The review states that nowadays classrooms are usually reaching uncomfortable temperatures (above 20 - 22°C), as schools are allowing the outdoor air supply becomes very low to save energy. They found that this causes CO2 levels to exceed 1000 ppm during school hours, which in turn reduces children's school performance by as much as 30%. In previous studies, improving ventilation rates from 3.0 L/s to 9.5 L/s, children improved the speed to developed language and numerical tests significantly. Also, the percentage of errors in the numerical tasks were significantly reduced. This means that doubling ventilation rates could increase schoolwork speed by 8%. Also, reducing air temperatures from 25 °C to 20 °C increased the performance in arithmetical and language tests significantly in terms of speed. Reducing the air temperature also decreased the number of errors. Therefore, decreasing the temperature by 1 °C would improve student performance in terms of speed by about 2%. They state that performance effects may be caused by distraction and discomfort, as well as the physiological effects of thermal discomfort. This environmental effect is greater on children than it has been found in adults. The authors conclude that a more sophisticated and sustainable approach to maintaining IEQ in classrooms is necessary to preserve student performance. [150]

Publication type: Journal article
Study type: Literature review
Studies reviewed: 7 studies

Wargocki, P., & Wyon, D. P. (2017). Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork. *Building and Environment*, 112, 359–366. https://doi.org/10.1016/j.buildenv.2016.11.020

Authors make a case for the different ways in which thermal comfort affects performance in both office and school settings. Regarding schoolwork, they go over a series of studies where temperatures above 25 ~C or 27 ~C affected the performance of children in different kinds of tasks. Regarding IAQ, they make a case for ventilation rates mentioning field intervention experiments where they increased air supply rates, and children were able to develop common school tasks faster. They state that it has not yet been possible to determine if subjective acceptance of thermal discomfort would be sufficient to remove the direct effects of physiological responses to performance. After reviewing four large experiments comparing self-estimated performance with actual performance, they conclude that self-estimated performance is not a good indicator of actual performance. It may indicate however, an increase in dissatisfaction with working conditions. They consider pollutants coming from the occupants and from the materials of the building itself. To measure these, they use CO2 as an indicator of the concentration of all bio effluents. They identify six mechanisms through which thermal comfort affects cognitive performance in people: attention or distraction, motivation to exert effort, arousal, manual dexterity, neurobehavioral symptoms, and

acute health symptoms. They also identify at least seven mechanisms through which indoor air quality affects cognitive performance: attention or distraction, motivation, arousal, neurobehavioral symptoms, and acute health symptoms, sleep quality, absenteeism. [151]

Publication type: Journal article
Study type: Theory development

Järvi, K., Vornanen-Winqvist, C., Mikkola, R., Kurnitski, J., & Salonen, H. (2018). Online questionnaire as a tool to assess symptoms and perceived indoor air quality in a school environment. *Atmosphere*, 9(7), 1–20. https://doi.org/10.3390/atmos9070270

Authors address how the indoor air quality of a school environment affected the health and well-being of students. The methods involved in this study involved 1,268 students, ages 5th to 9th grade, and 105 teachers in 36 classrooms at 6 different schools. All participants were given a questionnaire addressing their indoor air quality and the perceived effect participants believed it had. The study measured CO2 levels, complaints, and symptoms. The study found that teachers were more affected by the indoor air quality than students and reported more symptoms than the students did. The study also found that there were differences in IAQ between classrooms. The main differences were humidity, stuffy air, cold air and seemed to cause symptoms, such as tiredness, headache, skin symptoms, and dry/sore throats. The study also found that the IAQ of a school can be quickly assessed using a questionnaire and can highlight areas that need improvement. [152]

Publication type: Journal article
Study type: Case Study
Sample: 1,268 Students, 105 Teachers
Duration: Cross-sectional, Longitudinal
Age or developmental stage: 5th to 9th Grade

Light

Aumann, D., Heschong, L., Wright, R., & Peet, R. (2004). *Windows and Classrooms: Student Performance and the Indoor Environment.* HMG.

This study investigates whether daylight and other aspects of the indoor environment in elementary classrooms influenced student learning as measured by improvement on standardized tests over an academic year. The study compares the performance of 8000 3rd to 6th grade students in 450 classrooms in Fresno, CA, controlling for traditional variables such as demographics of teachers and students, as well as other physical attributes. Classrooms with a better view out of windows were positively and significantly associated with better student learning in standardized math and reading tests over an academic year. Other variables associated with

window glare, sun penetration and lack of visual control were associated with negative student performance. Other variables associated with IAQ, and acoustics were also significant. [153]

Publication type: Report
Study type: Field study
Sample: 8000 students in 450 classrooms
Duration: One academic year
Age or developmental stage: 3rd to 6th grade students

Baloch, R. M., Maesano, C. N., Christoffersen, J., Mandin, C., Csobod, E., De Oliveira Fernandes, E., & Annesi-Maesano, I. (2021). Daylight and school performance in European schoolchildren. *International Journal of Environmental Research and Public Health, 18(1), 1–12.* https://doi.org/10.3390/ijerph18010258

This study presents an analysis on the lighting data collected by the SINPHONIE (Schools Indoor Pollution and Heath: Observatory Network in Europe) project. The project collected physical measurements and questionnaire responses from 2670 school children, ages 8 to 13 in 155 classrooms from 53 schools across 12 European countries. The physical measurements included data on the physical features of classrooms as well as environmental measurements. The questionnaires included information on perceptions of lighting. The study found positive relationships between performance scores and types of window shading, latitude, percentage of window facing south and glazing, with the largest impact due to window-to-floor area ratio. [154]

Publication type: Journal article
Study type: Secondary analysis
Sample: 2670 school children in 155 classrooms from 53 schools
Duration: Single point in time, cross-sectional
Age or developmental stage: children ages 8 to 13

Berman, S., Navvab, M., Martin, M. J., Sheedy, J., & Tithof, W. (2006). A Comparison of traditional and high colour temperature lighting on the near acuity of elementary school children. *Lighting Research & Technology,* 38(1), 49–50. https://doi.org/10.1177/136578280603800114

In this study they assessed the visual acuity of children under different lighting conditions. They recruited 27 children ages 10-11 from fourth and fifth grade and a certified optometrist assessed their visual acuity suing Bailey-Lovie letter charts at 400 mm distance. The room had two conventional ceiling fluorescent lamps of CCT 3600 K or 5000 K. They assessed three lighting conditions: either both lamps providing equal task luminance or task and room luminance from the 5500 K lamps 50% lower. For the equal luminance condition, the higher CCT lamp showed a significantly better visual acuity ($p < 0.001$) for 24 of the 27 children. They also found that under the lower luminance condition, children had significantly less visual acuity for the 5500 K, but there was no significant difference between the 3600 K lamps at the higher luminance in contrast to the 5500 K lamps at the lower luminance. [155]

Publication type: Journal article

Study type: Experimental study
Sample: 27 children
Duration: Single point in time, three exposures
Age or developmental stage: 10-11 years old

Choi, K., & Suk, H. J. (2020). The gradual transition from blue-enriched to neutral white light for creating a supportive learning environment. *Building and Environment, 180, 107046.* https://doi.org/10.1016/j.buildenv.2020.107046

This paper presents 2 experiments where they investigated an ambient control scenario that helped maintain circadian entrainment, while supporting the cognitive performance of students. On experiment one, a total of 40 college students, 22 years old on average were exposed to four lighting conditions in a single session. They closed their eyes when changing each condition, and then developed a mathematical task. When they perceived a change, they also solved a questionnaire. The study found that students could perceive a 5 K/s rate change in lighting, but this didn't interfere with their concentration. The threshold at which participants perceived the change was 5000 K. The second study investigated the effect of lighting on physiological and subjective responses. They used EEG and ECG were used to assess students' reactions to 3 lighting scenarios (controlled or color-tuned lighting, constant neutral white light, and lights off conditions) with 10-minute exposures. A total of 23 12th graders participated in the experiment. The study found that concentration and arousal were highest in the controlled scenarios, but these effects were not reflected in the subjective assessments. [156]

Publication type: Journal article
Study type: Experimental study
Sample: Two studies: 40 college students, and 23 seniors
Duration: Four different exposures. Single point in time
Age or developmental stage: 22 years-old college students and 12th graders

Choi, K., & Suk, H.-J. (2016). Dynamic lighting system for the learning environment: performance of elementary students. *Optics Express,* 24(10), A907. https://doi.org/10.1364/oe.24.00a907

This study investigates elementary students' physiological, cognitive and behavioral responses to light color though 3 different experiments. The first two were laboratory studies, and the third one was a field study. In the first study they used 17 24-year-old students and measured physiological responses as a mediator of performance, but their results were not conclusive. In the second study, they observed cognitive and behavioral responses during academic and recess activities of 31 fourth grade students. The students were exposed to 3 lighting stimuli in random order for 30 minutes. They found significant differences in cognitive measurements related to the activities, but not to the lighting stimuli. The final experiment used 2 fourth-grade classrooms with 27 students each. One classroom was used as control. The intervention classroom was exposed to fluorescent lighting for a week, and to LED lighting for a second week. The students developed arithmetic problems and subjective assessments of 3 lighting stimuli. They found significant effects of lighting CCT (Correlated Color Temperature) with

subjective appropriateness, as well as with significant effects of lighting in both recess and academic activities. They also found that the percentage of correct answers increased in the experimental group using a pretest-posttest t-test. They found that the percentage of correct answers was highest in the 6500 K lighting. [157]

Publication type: Journal article
Study type: Experimental studies and Quasi-experimental study
Sample: (3 studies) 17 students, 31 students and 54 students.
Duration: (3 studies) Cross-sectional, Longitudinal, Single point in time
Age or developmental stage: 24-year-olds and fourth-graders

Dahlan, A. S., & Eissa, M. A. (2015). The Impact of Day Lighting in Classrooms on Students' Performance. *International Journal of Soft Computing and Engineering (IJSCE),* 6, 2231–2307. https://pdfs.semanticscholar.org/ed73/c9d3e4a71ed3b-2f060ae1ee8edd840f9d03f.pdf

This study explores the relationship between the presence of daylight and student performance over the course of a year. Dahlan et al. measured illuminance in 20 classrooms (400 students) over the course of a year, as well as other environmental variables to control for confounders. They performed a correlational statistical analysis to assess the relationship between different environmental factors and students' GPA. They found a significant correlation between light and student GPA. [158]

Publication type: Journal article
Study type: Field study
Sample: 400 students
Duration: One year
Age or developmental stage: Undergraduates

French, A. N., Ashby, R. S., Morgan, I. G., & Rose, K. A. (2013). Time outdoors and the prevention of myopia. *Experimental Eye Research*, 114, 58–68. https://doi.org/10.1016/j.exer.2013.04.018

This paper reviews the existing evidence on the hypothesis that children who spend more time outdoors are less likely to be or become myopic. The review states that the effect of time outdoors is robust, and that there is strong evidence to support the hypothesis. Time outdoors reduces other factors that are associated with myopia, such as large amounts of near work. The review finds that at this moment it is still not clear whether time outdoors also regulated the progression of myopia. [159]

Publication type: Journal article
Study type: Literature review

Fielding, R. (2006). Learning, lighting and color: Lighting design for schools and universities in the 21st Century. *DesignShare* (NJ1), 1–7.

Fielding describes how the current style of teaching and schools is not helping

modern students truly learn. This is also affected by the current illumination levels that exist in the classroom. Fielding looks at the older style of learning where students are focused on the "teaching wall". Kids now learn better by being challenged and learning various things that did not exist as a job before. The learning environment is something that, according to Fielding, needs to be varied in terms of the visuals such as lighting. Fielding also identified patterns of learning that helped in designing spaces for students that takes advantage of the full range of human capabilities. To achieve such a range, the schools need a well-rounded mix of indoor and outdoor spaces, including, quiet, reflective areas; messy, lab-like spaces; and social watering-hole spaces. Such spaces need somewhere for students to rest their eyes and take a quick mental break. [160]

Publication type: Article
Study type: Commentary

Gilavand, A., & Hosseinpour, M. (2016). Investigating the Impact of Lighting Educational Spaces on learning and educational achievement of elementary students. *International Journal of Pediatrics,* 4(2), 1387–1396. https://doi.org/10.22038/ijp.2016.6439

This study investigates the impact of lighting in elementary student performance. The study uses a random sample of 210 elementary students. Authors used the Hermance's achievement motivation questionnaire, a researcher-constructed questionnaire (observation checklist), student interviews and physical measurements to conduct the study. Their results showed that lighting had a significant influence on student achievement, based on student's self-reported perceptions. [161]

Publication type: Journal article
Study type: Field study
Sample: 210 students
Duration: Cross-sectional, Single point in time
Age or developmental stage: 3rd, 5th and 6th grade

Gentile, N., Goven, T., Laike, T., & Sjoberg, K. (2018). A field study of fluorescent and LED classroom lighting. *Lighting Research and Technology,* 50(4), 631–650. https://doi.org/10.1177/1477153516675911

In this study Gentile et al. compared the effects of LED and fluorescent lighting in four high school classrooms. Two classrooms in the study were fitter with T5 fluorescent tubes, while two classrooms were fitted with an experimental LED system. Over a year, 72 students (17 – 18 years old) performed their usual academic activities. The researchers measured students' mood, light perception and saliva cortisol concentration, as well as the light environment and electricity consumption of the classroom. The study contemplated the activity, individual factors, social environment and physical environment variables that affected the quasi-experimental setting. The study rendered only marginal differences between the lighting systems. Also, the LED rooms were slightly preferred, and only achieved minimal energy savings. [162]

Publication type: Journal article

Study type: Quasi-experimental study
Sample: 72 students
Duration: One academic year of measurements, questionnaires and biological tests performed 5 times
Age or developmental stage: 17-18 years old

Grangaard, E. M. (1993). Effects of color and light on selected elementary students. *UNLV Retrospective Theses & Dissertations.* https://doi.org/10.25669/v2gu-qav4

This study presents a replication of a previous 1981 study. The study compared children's off-task behavior and physiological response in a normal classroom setting with a prescribed classroom setting that used grey and blue colors, and full spectrum lighting. The study had 3 phases, two in the normal classroom in the beginning and end of the study for 10 days, and one in the middle for another 10 days. Twelve 6-year-old children participated in the study (6 boys and 6 girls). The researcher recorded blood pressure readings twice a day in the morning and afternoon and videotaped the study. He found a 9% decrease between the first and the second phase of the study, as well as a decrease in off-task behavior of 24%. [163]

Publication type: Journal article, Commentary, Report, Book, Doctoral Dissertation
Study type: Quasi-experimental study
Sample: 6 students
Duration: 30 days
Age or developmental stage: 6 years old

Hathaway, W. E. (1995). Effects of School Lighting on Physical Development and School Performance. *Journal of Educational Research*, *88*(4), 228–242. https://doi.org/10.1080/00220671.1995.9941304

Hathaway investigates how different lighting can affect student dental health, growth and development, attendance, and academic achievement. Hathaway explored four different types of artificial light sources: (a) full-spectrum fluorescent lamps, (b) full-spectrum fluorescent lamps with ultraviolet light supplements, (c) cool white fluorescent lamps, and (d) high-pressure sodium vapor lamps to see how they affected the students' health. Baseline data on 327 students completing Grade 4 were collected at the start of the study in June 1987 and on 233 students in June 1989 in 5 schools. He used nurse-reported information on general health, children's dental histories from a previous study, monthly attendance information, and standardized test scores as measures. The results of the 2-year study indicated that "students under full spectrum fluorescent lamps with ultraviolet supplements developed fewer dental cavities and had better attendance, achievement, and growth and development than did students under other lights. Students under the high-pressure sodium vapor lamps had the slowest rates of growth and development as well as the lowest levels of attendance and achievement". [164]

Publication type: Journal article
Study type: Field study
Sample: 560 students, 5 schools

Duration: two years
Age or developmental stage: 4th grade

Heschong, L. (1999). Daylighting in Schools: An Investigation into the Relationship between Daylighting and Human Performance. Detailed Report. *Hmg-R-9803*, 140. http://eric.ed.gov/?id=ED444337

This study looks at the relationship between daylighting and performance in schools. This study examined 21000 records from three school districts in the United States, covering over 2000 classrooms, over an academic year. The study found that students in classrooms with most daylighting advanced 20% faster on math tests and 26% faster on reading tests. Similarly, the students with the largest windows progressed 15% faster in math and 23% faster in reading. In classrooms with operable windows students' academic progress was 7 to 18% faster than in those with fixed windows. The findings were consistent across different types of schools. [165]

Publication type: Report
Study type: Field study
Sample: Over 200 classrooms, over 21000 school records
Duration: Longitudinal, One academic year
Age or developmental stage: grades 2nd to 5th

Hopkinson, R. G. (1949). Studies of Lighting and Vision in Schools. *Lighting Research and Technology, 14(8 IEStrans), 244–268.* https://doi.org/10.1177/147715354901400802

This paper presents a study developed with a random sample of children in schools in London investigating the effects of illumination and chalkboard reflection factor in the classroom on children with different levels of visual acuity. They found that the standard at the time of 10 lumens/sqft was adequate for children sitting near the chalkboard. Nonetheless, the paper states the need for improvements in illumination levels for ease of reading and makes an argument to include lighting considerations as part of the design of the classroom. [166]

Publication type: Journal article
Study type: Research study
Sample: 95 children
Duration: Single point in time
Age or developmental stage: 10 to 14 and 6 to 9 year olds

Keis, O., Helbig, H., Streb, J., & Hille, K. (2014). Influence of blue-enriched classroom lighting on students' cognitive performance. *Trends in Neuroscience and Education,* 3(3–4), 86–92. https://doi.org/10.1016/j.tine.2014.09.001

Authors explore the effects of blue-enriched white light in the morning on adolescents' performance in school. The study used a sample of 58 high school students from four classes in two schools for 5 weeks. In each school, the researchers performed an intervention of adding blue-enriched white lighting in one classroom, while the classroom next door was used as a control. The authors used psychological pre and post tests to measure

cognitive performance. They found that in comparison to standard lighting, the students from the intervention classroom showed faster processing speed and better concentration. They found that the blue-enriched white lighting seemed to influence very basic information processing primarily, as no effects on short-term encoding and retrieval of memories were found. They found a main effect of time, which they attributed to learning what to expect form a particular test. They found four significant interaction effects, and only the verbal memory interaction effect failed to reach significance. This study was designed to explore the influence of exposure to blue-enriched white light in the morning on the performance of adolescent students. 58 High school students were recruited from four classes in two schools. In each school, one classroom was equipped with blue-enriched white lighting while the classroom next door served as a control setting. The effects of classroom lighting on cognitive performance were assessed using standardized psychological tests. Results show beneficial effects of blue-enriched white light on students' performance. In comparison to standard lighting conditions, students showed faster cognitive processing speed and better concentration. The blue-enriched white lighting seems to influence very basic information processing primarily, as no effects on short-term encoding and retrieval of memories were found.[167]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 58 students
Duration: 5 weeks
Age or developmental stage: High school (16 to 20)

Knoop, M., Stefani, O., Bueno, B., Matusiak, B., Hobday, R., Wirz-Justice, A., Martiny, K., Kantermann, T., Aarts, M. P. J., Zemmouri, N., Appelt, S., & Norton, B. (2020). Daylight: What makes the difference? *Lighting Research and Technology*, 52(3), 423–442. https://doi.org/10.1177/1477153519869758

This paper covers different effects and benefits of daylight for humans. The review emerged from discussions on a seminar in Berlin in 2018 and is not meant to be a systematic review. The topics reviewed: visual performance, good eyesight, circadian entrainment, Acute, non-image forming effects (such as melatonin suppression, increase of heart rate or alertness, circadian responses), room object and human appearance, (emotional state), comfort, well-being through views, energy efficiency, and monetary value. The review finds that there are still some knowledge gaps regarding the benefits of daylight like the positive effect of contextual clues provided by a view, and the higher onset of visual discomfort glare. The review points in the direction of further research addressing the impact of daylight on some aspects of human performance, health and behaviors that may translate into economic benefits. The use of light in built environments has comfort, behavioural, economic and environmental consequences. Daylight has many particular benefits including excellent visual performance, permitting good eyesight, effective entrainment of the circadian system as well as a number of acute non-image forming effects and the important role of vitamin D production. Some human responses to daylight seem to be well defined whilst others require more research to be adequately understood. This paper presents an overview of current knowledge on how the characteristics of daylight play a

role in fulfilling these and other functions often better than electric lighting as conventionally delivered.[168]

Publication type: Journal article
Study type: Non-systematic literature review

Konstantzos, I., Sadeghi, S. A., Kim, M., Xiong, J., & Tzempelikos, A. (2020). The effect of lighting environment on task performance in buildings – A review. *Energy and Buildings,* 226, 110394. https://doi.org/10.1016/j.enbuild.2020.110394

This paper reviews and summarizes the available information on the effect of lighting on task performance. It goes through the measures that have been used to assess task performance, including of performance tests on cognitive performance and perception, visual acuity and reaction, memory, reasoning, and labor productivity. Also, it looks at the parameters that have been evaluated in previous literature, such as illuminance, luminance ratio, and correlated color temperature (CCT), and their effects on task performance. Different experimental design methods, participants and settings were reviewed and categorized, along with assessment and evaluation methods. The authors state that tough no universal conclusions can be made, it appears that task performance improves at higher illuminances, contrast ratios in the range of 7:11, and higher CCT. They conclude that future studies should also include the effects of vertical illuminance, daylight provision, and outside views on task performance. [169]

Publication type: Journal article
Study type: Literature review

Michael, A., & Heracleous, C. (2017). Assessment of natural lighting performance and visual comfort of educational architecture in Southern Europe: The case of typical educational school premises in Cyprus. *Energy and Buildings,* 140, 443–457. https://doi.org/10.1016/j.enbuild.2016.12.087

Authors investigated the lighting comfort for a typical school in Cyprus. They looked at two types of rooms, those with a linear semi-open corridor and ones with a clerestory. The classrooms were all the same with desks oriented lengthwise along the windows in rows. A teacher's desk is along the wall that the students face. This layout is the one that they used in the software research to help them fully understand what was going on in terms of the light. They also looked at another school to use as a representative case study due to its typical characteristics in terms of the typology, construction as well as integration of environmental design principles. When looking at the data, it shows that the different classrooms performed differently mainly because the rooms with a clerestory didn't have anything to help diffuse the light. [170]

Publication type: Journal article
Study type: Research Study
Sample: Field questionnaires: 400 students, 46 teachers. General analysis: 114 buildings
Age or developmental stage: Field questionnaires: 13 to 15 years-old

Mirrahimi, S., Ibrahim, N. L. N., & Surat, M. (2012). Effect of daylighting on student health and performance. *Computational Methods in Science and Engineering,* 5(4), 127–132.

This paper presents a nonsystematic review of the effects of daylighting on physical and psychological health and student performance. The review finds that previous studies have found association of daylighting with improved eye function, vitamin D and regulation of circadian rhythms, while it has been associated with the reduction of cancer, stress and microbes. Regarding psychological effects, daylighting has been found to improve security, mood, sleep and comfort, while it has been associated with the reduction of stress, depression, violent behavior and seasonal affective disorder. Finally, the review mentions that daylight has been associated with enhanced student performance, especially through test scores. [171]

Publication type: Journal article
Study type: Literature review

L. Morrow, B., & M. Kanakri, S. (2018). The impact of fluorescent and led lighting on students attitudes and behavior in the classroom. *Advances in Pediatric Research.* https://doi.org/10.24105/apr.2018.5.15

This paper presents a literature review on the effects of high correlated color temperature (CCT) of LED and fluorescent lighting on students in classroom settings, as well as the results from a questionnaire teachers' perceptions on how lighting influences students' performance and behavior. Their literature review revealed that higher CCT lighting had been found to positively affect attitudes and behavior. A set of 75 pre-K through high school teachers responded to a questionnaire that displayed pictures of classrooms with different CCT. The study found that most teachers selected images with higher kelvin temperatures as encouraging positive affect, alertness, and energy. Similarly, the image with lower Kelvin was associated with encouraging calm mood. They found mixed results regarding perceptions of lighting for task-behaviors and focus. [172]

Publication type: Journal article
Study type: Literature review and Research Study
Sample: 75 pre-K to high school teachers
Duration: Single point in time

Mott, M. S., Robinson, D. H., Walden, A., Burnette, J., & Rutherford, A. S. (2012). Illuminating the effects of dynamic lighting on student learning. *SAGE Open, 2(2), 1–9.* https://doi.org/10.1177/2158244012445585

In this quasi-experimental design, Mott et al. studied an artificial lighting system with four discrete settings (focus, energy, calm, and normal), and concentrated on the "focus" setting. They investigated the effects of color temperature, and illumination on motivation, concentration, and oral reading fluency performance. A total of 84 third graders were exposed to either focus (6000K-100fc average maintained) or normal lighting over a calendar year. They instructed the teachers to leave the blinds closed during the study, to control for atmospheric conditions, and either exposed the students to

normal or treatment conditions. They couldn't control for teacher effects. The students were tested 3 times (September, January, May) using an Oral Reading Fluency (ORF), a motivation questionnaire and a d2 test of concentration. The study found that focus lighting led to a higher percentage of increase in oral reading fluency performance (36%) than control lighting (17%). They didn't find any lighting effects for motivation or concentration, which the authors think might be due to the younger age level of respondents. [173]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 84 students
Duration: Longitudinal, one year
Age or developmental stage: Third graders (7 to 8 years old)

Moyano, D. B., Fernández, M. S. J., & Lezcano, R. A. G. (2020). Towards a sustainable indoor lighting design: Effects of artificial light on the emotional state of adolescents in the classroom. In *Sustainability (Switzerland) (Vol. 12, Issue 10).* https://doi.org/10.3390/su12104263

This paper presents a literature review on the available evidence on the effects of artificial light on adolescents. Regarding light in classrooms, they emphasize the need for energy savings in educational settings. They also touch upon the recent proposal of new metrics to assess daylight including time of day and season. They also found an abundance of publications on the negative effects of poor lighting. These problems have been found to cause temporary visual, psychological and permanent problems of the visual system. Other negative effects have been found on children such as performance and mood. They also touch upon the need for children to receive natural light to avoid an increase in child myopia. Finally, they find literature on the effects of classroom lighting on student performance, where poor lighting was associated with inadequate hormone levels, which led to negative effects on children's behaviors. They also found studies correlating natural light or a combination of natural and artificial light with increased student performance. [174]

Publication type: Journal article
Study type: Literature review
Age or developmental stage: adolescents

Münch, M., Wirz-Justice, A., Brown, S. A., Kantermann, T., Martiny, K., Stefani, O., Vetter, C., Wright, K. P., Wulff, K., & Skene, D. J. (2020). The Role of Daylight for Humans: Gaps in Current Knowledge. *Clocks & Sleep, 2(1), 61–85.* https://doi.org/10.3390/clockssleep2010008

This paper presents the results of a workshop looking at the current state ok knowledge regarding the effects of daylight in humans. The paper organizes the gaps in daylight research in 3 topics: quantity and quality for physiological and psychological functioning, measurement and assessment monitoring methods and insufficient integration between knowledge coming from different disciplines. In the first gap, the paper mentions the existing uncertainties for the effects of daylight and visual comfort and vision when

comparing daylight and electric light, as well as gaps on behavior and physiology other than visual, circadian rhythms, light sensitivity functions, daylight as a therapeutic treatment, risks of light exposure, individual differences, daylight for work conditions, and daylight and environmental factors. The paper briefly mentions the uncertainties regarding the differences between light effects in children and adults, as well as the need for more light research in schools. [175]

Publication type: Journal article
Study type: Literature review

Pearce, L. (2016). Non-normative use of windows and artificial lighting in selected South Australian primary schools. Fifty Years Later: Revisiting the Role of Architectural Science in Design and Practice: 50th International Conference of the Architectural Science Association 2016, 597–606.

This paper presents a post-occupancy evaluation in selected primary schools in Australia, where they assess of artificial light and window use patterns. They developed observations in 4 schools, in 20 teaching spaces including classrooms and library/ resource spaces. A sample of 147 students ages 10 to 13, and 44 staff members were recruited for the study. They performed measurements over a year, but only used a sample from October to December to develop the study. All the spaces they observed had natural light, but they found differing perceptions regarding lighting types. While students preferred daylighting for learning, the staff deemed artificial lighting more appropriate. They found that artificial lighting wasn't always used when light levels were below the standard, and that windows were often obstructed by student work, furniture and pedagogical displays controlled by the teachers. They also found with the introduction of new, interactive white boards, schools required better daylight and glare control. The study concludes that the spatial agency of the classroom regarding lighting conditions appears to be restricted to the teaching staff. [176]

Publication type: Journal article
Study type: Field study
Sample: 20 classrooms and library instruction spaces, 147 students, 44 staff
Duration: Three months
Age or developmental stage: 10 to 13 years old

Plympton, P., Conway, S., & Epstein, K. (2000). Daylighting in Schools: Improving Student Performance and Health at a Price Schools Can Afford. *American Solar Energy Society Conference, 4–10.*

This report starts by briefly discussing a small set of landmark daylighting studies that have found significant relationships between daylighting and student performance and wellbeing. Then, it presents four case studies of schools in different parts of the US where they have developed daylighting interventions. It presents quotes from principals of the schools, where they talk about the benefits of these interventions. Among the benefits they mention are increased attendance and well-being, and increased interest from parents wanting their children to attend their school. The estimated savings from the daylighting interventions in the case studies presented go

from $9,000 to $32,000. [177]

Publication type: Conference paper
Study type: Case studies
Sample: 4 case studies

Pulay, A., Read, M., Tural, E., & Lee, S. (2018). Examining student behavior under two correlated color temperature levels of lighting in an elementary school classroom. *Educational Planning*, 23(3), 58–69.

This paper presents a quasi-experimental study where they assess the influence of two fluorescent lamps if different CCT on student on-task behaviors in the classroom. Pulay et al. hypothesized that students would display more on-task behaviors with a CCT level that resembled natural light. They tested a 4100 K and a 3000K lamp in two second grade classrooms (27 students, 7 to 8 years old) over the course of five months. They performed non-participant observations of on task behavior and behavior mapping techniques, using recordings of the classroom activities every 5 seconds for minutes and every 15 minutes respectively. They found that the higher CCT of the lighting was related with more student on-task behaviors (p = 0.038), even when more male students moved around the room. [178]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 2 classrooms, 27 students
Duration: 5 months
Age or developmental stage: 2nd grade, 7 to 8 years old

Pulay, A., & Williamson, A. (2019). A case study comparing the influence of LED and fluorescent lighting on early childhood student engagement in a classroom setting. *Learning Environments Research,* 22(1), 13–24. https://doi.org/10.1007/s10984-018-9263-3

This study explores the differences between fluorescent lighting and LED lighting in pre-K students. They used a sample of 23 students 3-4 years old. They installed new fluorescent lamps and left a 2-week period of adjustment. Later, they developed 2 weeks of participant observations of student engagement behaviors. The same procedure was followed using LED lamps with the same CCT. They used the Emergent Academic Snapshot Observational Method to assess student engagement, recorded by three researchers, using time-interval sampling. They found that students were significantly more engaged under the LED lamps, in both regular students, and students with disabilities (n=5). [179]

Publication type: Journal article
Study type: Case study
Sample: 23 students (5 with disabilities)
Duration: 2 weeks per exposure, 2 exposures
Age or developmental stage: 3-4 years old

Saffidine-rouag, D., & Zerouala, M. (2000). Criteria to Consider Prior to a Lighting Design of a Classroom.

In this paper the authors go through basic guidance for lighting design in primary school classrooms, considering the tasks performed within classrooms, the type of occupants and their visual requirements, the tasks prevailing in time and the visual performance needed for each one, and the visual performance and the major role of perception. They conclude that tasks within classrooms should be performed with minimum physiological effort and some psychological relaxation, and highlight the roles of designers and teachers to provide visual comfort in the classroom. [180]

Publication type: Journal article
Study type: Literature review

Sansal, K. (2012). Time-dependent effects of indoor lighting on well-being and academic performance. *Doctoral Thesis, UCL (University College London).*

This doctoral dissertation explores the effects of indoor lighting on students' academic performance. Sansal carries out two case studies in different latitudes to support his findings. He performed the first case study between June and October in Kent, UK with 56 fourth graders (4 classrooms), and gathered data in 4-week intervals. For the second study, he collected data from 79 third graders in Ankara Turkey for 15 days in January and collected data twice. In both cases he collected information on the academic performance of students. In the first study he found that natural light was important for non-visual effects. In the second study, he confirmed that participants who were exposed to more natural light felt less sleepy, and had better sleep quality and mood overall. The present research was designed to address the questions raised by the literature and clarify the non-visual effects of indoor lighting by carrying out two field studies at two different latitudes. During the period between the 8th of October 2008 and 10th of June 2009, the first field study was conducted in four similar classrooms of a junior school in Kent, U.K. The classrooms differed in the provision of artificial illumination and daylight. The study population consisted of fifty-six, fourth-grade students, aged between eight and nine years. Throughout the study, five main and five supplementary data collections were executed at approximately four-week intervals to assess participants' sleep quality, mood and sleepiness by administering self-reports and also their diurnal melatonin and cortisol concentrations by collecting saliva samples. Additionally, data regarding participants' performance on school examinations were collected to evaluate academic achievement. The results of the study revealed that natural light itself might be a potent factor in promoting the non-visual effects. Therefore, the second field study was conducted during the period between the 5th of January 2011 and 20th of January 2011 to verify the findings. The study was conducted in two similar classrooms of a junior school in Ankara, Turkey. The classrooms differed only in the provision of daylight. The study population consisted of seventy-nine, third-grade students, aged between eight and nine years. Throughout the study, two data collections were executed to assess participants' sleep quality, mood and sleepiness by administering self-reports. Additionally, data regarding participants' performance on school examinations were collected to assess academic progress. The second field study confirmed the findings

form the previous field work. The participants who were exposed to more natural light at eye level reported significantly less daytime sleepiness and better sleep quality and overall mood. Moreover, their scholastic performance was comparatively better. Complementary information on the physiological, psychological and cognitive effects of indoor lighting that can be linked to our biophilic tendencies and Environment of Evolutionary Adaptedness is provided by the results of the two field studies. [181]

Publication type: Doctoral Dissertation
Study type: Field study
Sample: Two studies: 56 children and 79 children
Duration: 5 months and 2 weeks
Age or developmental stage: 3rd and 4th grade

Sansal, K. E., Edes, B. Z., & Binatli, A. O. (2008). Effects of Indoor Lighting on Depression Probability and Academic Performance in a Population of Turkish Adolescents. *Experiencing Light 2012,* 2001, 1–4. http://2012.experiencinglight.nl/orals.html

This paper examines the relationship of indoor lighting and depression in adolescents. The authors developed a case study measuring light levels in 9th grade classrooms with a total of 275 students for a whole month. To assess depressive moods, they gave the students the Turkish version of the Children's Depression inventory test every 2 weeks. Also, they got access to students' test results in math, biology, history, chemistry, and physics to assess performance. Through a probability logit model, they found that the probability of depression was significantly lower for male students. They also found a causal relationship between low grades and depression. However, they didn't have enough evidence to deduce a relationship between academic performance and vertical illuminance. The study is limited as it doesn't control for SES factors. [182]

Publication type: Conference paper
Study type: Field study
Sample: 275 students
Duration: One month
Age or developmental stage: 9th grade

Shishegar, N., & Boubekri, M. (2016). Natural Light and Productivity: Analyzing the Impacts of Daylighting on Students' and Workers' Health and Alertness. *International Journal of Advances in Chemical Engineering and Biological Sciences, 3(1).* https://doi.org/10.15242/ijacebs.ae0416104

This paper presents a literature review on how light influences student performance, and touches upon issues of time and exposure light. It mentions that light has visual and non-visual effects, and that sunlight appears to be the most effective light source, as it also plays a role in human health for the production of vitamin D, improvement of mood, attention, cognitive performance, physical activity, sleep quality and alertness. Regarding studies with students, it comments on a study that found that morning light brought a 30-minute delay in the circadian rhythm of 8th grade students, and one that proved that blue-enriched whit lighting had an effect on basic information processing in high school students. They state that light interventions in

school could be beneficial to enhance alertness and performance. [183]

Publication type: Conference paper
Study type: Literature review

Susan, M. Y., & Prihatmanti, R. (2017). Daylight characterisation of classrooms in heritage school buildings. *Planning Malaysia,* 15(1), 209–220. https://doi.org/10.21837/pmjournal.v15.i6.236

This paper presents a case study of two high schools in adaptively reused historic buildings that are next to each other in Subraya (Lat. 7°S). The study aimed at evaluating the characteristics of daylight in the two buildings. To develop the study, they divided the classroom in a 1m x 1.2m grid to measure the illuminance levels. The measurements were taken in September 2015 at 0.75m height. Only one representative classroom for each school was measured. The study found that the indoor light levels in both schools were below standard, so artificial lighting had to be used during all the school day. Daylight was insufficient and not evenly distributed. The paper concludes by stating that it is problematic to deal with interventions on heritage buildings for lighting purposes, so interior finish interventions are preferred. [184]

Publication type: Journal article
Study type: Field study
Sample: 2 classrooms
Duration: Single point in time

Sojoudi, S., & Jaafar, M. F. Z. (2012). Indoor Lighting of the Classes and Its Effects. *6thSASTech 2012,* Malaysia, Kuala Lumpur, April, 1–8.

This paper presents a non-systematic literature review on the impact of light on task performance, comfort and behavior. The paper looks at intensity, glare, and the differences between natural, full-spectrum, and cool-white fluorescent lights. The paper states that several studies have addressed lighting in the classroom, as well as chemical and biological fluctuations, and light quality. It follows by stating that these studies might serve schools to make a case for effective lighting, as they have found that lighting can an increase test scores by even five percent. Finally, it states that studies have found that even changes from cool-white to full-spectrum fluorescent can be markedly beneficial in schools where daylighting isn't possible. [185]

Publication type: Conference paper
Study type: Literature review

Sleegers, P. J. C., Moolenaar, N. M., Galetzka, M., Pruyn, A., Sarroukh, B. E., & Van Der Zande, B. (2013). Lighting affects students' concentration positively: Findings from three Dutch studies. *Lighting Research and Technology,* 45(2), 159–175. https://doi.org/10.1177/1477153512446099

In this paper the authors present 3 different studies where they assessed the influence of illuminances ranging from 350 to 1000 lux, and their corresponding color temperatures on the concentration of elementary school children. The first two were quasi-experimental pretest - posttest studies

where they used a flexible and dynamic lighting system with 89 students from 2 schools for 1 day, and 37 students from two classrooms over a month. The third study was performed in a laboratory with 55 students from grades 4 to 6 and was designed to be only a post-test study. In all the studies, they used the d2-test to measure the concentration of the students in terms of speed and accuracy. Overall, they found that lighting has a positive influence on children concentration. They found differences between the effects of lighting in different grades. Their results suggest that older students might be less affected by lighting than younger ones, but they state that other factors may explain these differences. The third study didn't find significant differences on student concentration. They state that to assess the effects of lighting setting, exposure and relations to different tasks, further studies are necessary. [186]

Publication type: Journal article
Study type: Experimental and Quasi-experimental study
Sample: three studies: 89 students, 37 students and 55 students
Duration: One day, one month, one morning of exposure
Age or developmental stage: 4th to 6th grades

Veitch, J. A., & Newsham, G. R. (1996). Determinants of lighting quality II: Research and recommendations. Annual Convention of the American Psychological Association Toronto, Ontario, Canada, 1–38. https://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc40343.pdf

This literature review aims at defining conditions that are associated with lighting quality. It focuses mostly on studies performed in office and school settings and touches on different issues of the luminous environment like the relationship between lighting and social interaction and communication. They found a need to increase behavioral research to identify the best luminous conditions for social interactions and communication, as well as range of important behavioral outcomes. They found that even when illuminance had the best scientific foundations, the existing biological and health evidence suggested that the current illuminance recommendations were too low. They also found conflicting results regarding glare and light uniformity. Finally, they found that indirect lighting was preferred over direct only systems, but that this wasn't the recommended practice. [187]

Publication type: Conference paper
Study type: Literature review

Winterbottom, M., & Wilkins, A. (2009). Lighting and discomfort in the classroom. *Journal of Environmental Psychology,* 29(1), 63–75. https://doi.org/10.1016/j.jenvp.2008.11.007

In this paper, the authors used a sample of 90 UK classrooms to examine them in terms of flicker from the fluorescent lights, illuminance at desks, and luminance of whiteboards with a projector. In the study, Winterbottom and Wilkins found that 80% of classrooms were lit with 100 Hz fluorescent lighting that could cause headaches and impair visual performance from the imperceptible 100 Hz flicker. Of all the rooms they studied, 88% were in

exceeding the recommended designed mean illuminance. There was also an 84% of the classrooms that exceeded levels beyond which visual comfort decreases. In some of the rooms that were looked at, most of them could not adequately be controlled due to classroom design. The projectors that were in the space caused reflection from the bulb in the projector. This resulted in an uncomfortable glare on the projected screen. [188]

Publication type: Journal article
Study type: Field study
Sample: 11 secondary schools, 90 classrooms
Duration: July through September

Wohlfarth, H. (1984). The effect of color-psychodynamic environmental modification on disciplinary incidents in elementary schools over one school year: A controlled study. *International Journal of Biosocial Research,* 6(1), 44–53.

This paper presents a quasi-experimental study where they exposed elementary school students to full-spectrum light, prescribed color and light /color combinations, ultra-violet light, and electromagnetic radiation. Four schools were involved in the study, where 3 acted as experimental groups and one as control. They measured student outcomes using pre and post standardized test results over the course of an academic year. They measured the visual acuity of students, as well as their blood pressure. Other measures such as student behaviors requiring disciplinary outcomes, and tests to measure psychological and affective changes were used as well. The study found no consistently significant results regarding cause-effect relations between "simulated outdoor light or prescribed colors or light/color combinations in the school environment and student ability or achievement levels, attitudes towards school subjects, misbehaviors warranting disciplinary action, absences due to illness, refractive eye problems or blood pressure." They did find a short-term effect of stimulating color increasing blood pressure between am and pm times. [189]

Publication type: Report
Study type: Quasi-experimental study
Sample: 4 schools. A different intervention in each one.
Duration: 10 months (1 academic year)
Age or developmental stage: 3rd and 5th graders

Yang, W., & Jeon, J. Y. (2020). Effects of correlated colour temperature of LED light on visual sensation, perception, and cognitive performance in a classroom lighting environment. *Sustainability (Switzerland),* 12(10). https://doi.org/10.3390/SU12104051

In this study they investigate the effects of different illuminance levels and their corresponding color temperatures on students' brightness sensation, lighting perception, and cognitive performance. They exposed 60 undergraduate students to LED conditions of correlated Color temperature (CCT) of 3000 K, 4000 K, and 5700 K, and illuminance of 650 lux and 1050 lux in actual university classrooms. The students participated in six 35-minute sessions in the experimental setting where they performed a working memory test and subjective questionnaires. The study found that 4000 K was deemed the optimal lighting for educational settings. An increase in CCT lead to an

increase in brightness sensation, but changes in CCT didn't linearly increase light comfort. They found that levels of perceptual properties, acceptance and satisfaction were not affected by changes in CCT from 3000 K to 5700 K. They found differences in glare sensations between women and men. [190]

Publication type: Journal article
Study type: Experimental study
Sample: 60 students
Duration: Six 35-minute sessions
Age or developmental stage: Undergraduates, early twenties

Lee, S., & Lee, K. S. (2019). A study on the improvement of the evaluation scale of discomfort glare in educational facilities. ***Energies***, 12(17). https://doi.org/10.3390/en12173265

Lee and Lee address how glare affects the indoor environment of schools and causes discomfort to students along with ways to scale glare and areas mainly affected by glare. The methods involved in this study were one high school in Seoul and a light environment simulation program to analyze light, glare probability (DGP), and discomfort due to glare. The study measured the discomfort of the space due to glare and compared them to potential standards. The study also measured where glare caused the most problems in the space and what the light environment simulation results showed when analyzed. The research study found that in the analysis and simulation that by using DIVA for Rhino-Grasshopper, a new light environment simulation program, there was the ability to accurately improve glare measurements. The study also found that the areas where glare was a major problem as shown in the data and could help to create a building without glare problems. [191]

Publication type: Journal Article
Study type: Research Study
Sample: 1 Classroom
Duration: Single Point in Time
Age or developmental stage: High School

Al-Sallal, Khaled A. (2010) Daylighting and visual performance: evaluation of classroom design issues in the UAE, International Journal of Low-Carbon Technologies, 5(4), 201-209. https://doi.org/10.1093/ijlct/ctq025

Al-Sallal addresses how visual performance and daylight in the United Arab Emirates and the classrooms are affected by these variables. The data collected, came from architectural drawings, compliance documents set by governmental bodies, photography, and site visits. The view and field of view of potential students in these classrooms were analyzed to understand how daylighting can affect the view in and outside of the classroom. The study involved visual quality, lighting direction, desk position, windows orientation, depth to height ratio, and spacing size. The study found that there were several problems with the maintenance levels affecting the field of view. High brightness from windows, an uneven disrupted background of light, specifically light, and the contrasting luminance on surfaces all

affected views. In some conditions, the luminance ratios did not meet the requirements between light sources and surroundings. The study concludes that the United Arab Emirates has several design issues in their stand classroom design including visual quality and daylighting. [192]

Publication type: Journal Article
Study type: Case Study
Sample: 7
Duration: Single Point in Time
Age or developmental stage: School Children, Primary and Older

Küller, R., & Lindsten, C. (1992). Health and behavior of children in classrooms with and without windows. *Journal of Environmental Psychology*, 12(4), 305–317. https://doi.org/10.1016/S0272-4944(05)80079-9

Kuller and Lindsten address how light affects classroom performance, body growth, sick leave, and stress hormones of school children. The study used around 90 children in their natural school environment for one school year. Four classrooms differed in access to daylight and artificial fluorescent light. Measurements of central power supply, window size, room size, and measurements of hormones were taken during the middle or second half of the week, and students needed to be in school for a few weeks, not around holidays. Measurements of urine were taken four times and behaviors were observed for thirty minutes during forty-minute lectures. The study found that there were more stress hormones in the summer when compared to the winter. Morning cortisol of high levels affected sociability and moderate or low levels promoted individual concentration for the students. Body growth was the smallest for children with the highest levels of morning cortisol. Children in the classroom without natural and artificial daylight did not have the same circannual rhythm of urinary-free cortisol. [193]

Publication type: Journal Article
Study type: Case Study
Sample: 90
Duration: Longitudinal, One School Year
Age or developmental stage: 8 to 9 Years Old

Views and indoor nature

Benfield, J. A., Rainbolt, G. N., Bell, P. A., & Donovan, G. H. (2015). Classrooms With Nature Views: Evidence of Differing Student Perceptions and Behaviors. *Environment and Behavior*, 47(2), 140–157. https://doi.org/10.1177/0013916513499583

Authors studied nine classrooms that have views of nature and compared them with nine classrooms that have windows that look to a concrete wall. The two types of classrooms had the same size, layout, number of students and course. They compared students' perceptions, midterm scores, and final scores. They developed a survey in the beginning of the course to use as

a control and compare the two classrooms. They did not find statistically significant results regarding midterm grades. However, there was a significant difference between the classrooms with and without views of nature for the final scores of the class. Similarly, classrooms with views of nature rendered significantly more positive perceptions of the class from students. The study has some limitations, such as controlling for instructor, which could change the results. [194]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 567 students
Duration: One course
Age or developmental stage: Undergraduates, 19 years old

Bogerd, N., Dijkstra, S.C., Tanja-Dijkstra, K., Boer, M.D., Seidell, J., Koole, S., & Maas, J. (2020). Greening the classroom : Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality. *Building and Environment*, 171, 106675. https://doi.org/10.1016/j.buildenv.2020.106675

Van den Bogerd, Dijkstra, Tanja-Dijkstra, de Boer, Seidell, Koole, and Maas address if students in a lecture in a classroom are affected by indoor nature in a classroom. Specifically, if the benefits of indoor nature like potted plants, and green walls do affect these students and their attention, health, and well-being. The study involved 70 students at a university, 213 students at a secondary school, and 161 students at a secondary vocational school. Students were measured and tested on their attention, health complaints, lecture evaluation, perceived environmental quality, and attention. Students were given attentional tasks and questionnaires to complete that were then measured. The study found that the perceived environmental quality of classrooms with indoor nature was more favorable than without nature. The study also found that after one lecture, secondary education students reported that they had greater attention, teacher evaluation, and lecture evaluation when in a classroom with indoor nature compared to one without. [195]

Publication type: Journal Article
Study type: Paper/Case Study
Sample: 444
Duration: Cross-sectional, Longitudinal
Age or developmental stage: University and Secondary Schools

Doxey, J. S., Waliczek, T., & Zajicek, J. M. (2009). The Impact of Interior Plants in University Classrooms on Student Course Performance and on Student Perceptions of the Course and Instructor, HortScience horts, 44(2), 384-391. Retrieved Aug 29, 2021, from https://journals.ashs.org/hortsci/view/journals/hortsci/44/2/article-p384.xml

Doxey, Waliczek, and Zajicek address how plants impact university students and their classrooms. The performance of students and their perceptions of the course and teacher were analyzed. The study involved 385 students in two classes and there were three sets of them. Tropical plants were placed in the classrooms throughout the semester, and the effect on performance was measured. In the control classroom, there were no plants. There was a survey on instructor evaluation and university courses given to the students.

The study found that there was a significant difference statistically when comparing the teacher and course evaluation scores based on tested and control groups. Specifically, there was a large difference statistically for the enthusiasm of the instructor, organization of the instructor, and learning when plants were and were not in the classrooms. The study also found that there was the largest apparent difference for the students in the windowless and stark classroom. [196]

Publication type: Journal Article
Study type: Case Study
Sample: 385
Duration: Cross-sectional, Longitudinal, One Semester
Age or developmental stage: University

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual Environment, Attention Allocation, and Learning in Young Children: When Too Much of a Good Thing May Be Bad. *Psychological Science*, 25(7), 1362–1370. https://doi.org/10.1177/0956797614533801

Fisher, Godwin, and Seltman address how the visual environment affects children and their ability to allocate attention and their ability to learn. The methods involved in this study were 24 students in kindergarten that were analyzed in a laboratory classroom. Students were separated into two groups with 12 students in each group. The measurements were in a laboratory classroom designed to have visual distractions that are found in primary classrooms. Measurements were taken over 2 weeks and seating was assigned randomly and assessments were given to students in a workbook. There were also measurements on the ability to stay focused while there were potential visual distractions. The study found that when walls were highly decorated with potential visual distractions, children were more distracted. Students also spent more time off task when there were visual distractions. The study also found that there were smaller learning gains for students when there were high visual distractions. [197]

Publication type: Journal article
Study type: Research Study
Sample: 24 students
Duration: Longitudinal, 2 weeks, Cross-sectional
Age or developmental stage: Kindergarten

Gou, Z., Khoshbakht, M., & Mahdoudi, B. (2018). The impact of outdoor views on students' seat preference in learning environments. *Buildings*, 8(8). https://doi.org/10.3390/buildings8080096

Gou, Koshbakht, and Mahdoudi address how views impact students, specifically their seat preference and learning environment. The methods involved in the study explored two main research questions. The research questions include: How do the view elements influence students' seating behaviors in learning environments? How important outdoor views are in seat selection in learning environments? There was a survey given to students at a university library in Gold Coast, Australia. The survey measured their seat preference, view elements, and occupancy rate. The study found that it echoed previous research that had shown that privacy and territoriality

are the main factors as to how students choose seats. The study found that views, specifically outdoor views impact seat selection. The study also found that sky views that also provide shading are seen as potential optimal outdoor view compositions. The study points to the importance of the ability to see changes besides only greenery outside the building. [198]

Publication type: Journal article
Study type: Research Study
Sample: 1 library
Duration: Longitudinal, Cross-sectional
Age or developmental stage: University

Han, K.-T. (2009). Influence of Limitedly Visible Leafy Indoor Plants on the Psychology, Behavior, and Health of Students at a Junior High School in Taiwan. *Environment and Behavior*, 41(5), 658–692. https://doi.org/10.1177/0013916508314476

Han addresses how visible indoor plants affect the physiology, behavior, psychology of students over one semester. The study used a quasi-experimental approach over one semester of two classes of sophomore students at a Taiwanese junior high, which meant they were in eighth grade. Seventy-six students were surveyed once every two weeks. Six plants were placed in the classrooms in the back to be viewed but to not get in the way. The study found that the experimental groups reported comfort, friendliness, and performance stronger than the control group. There were fewer punishment records due to misbehavior in the experimental group compared to the control group. There were also fewer sick leave hours in the experimental group compared to the control group. The study also found that visual and psychological mechanisms were at work in these classrooms due to plants, but other factors could also have affected the results. [199]

Publication type: Journal article
Study type: Case Study
Sample: 76
Duration: Longitudinal, Two weeks
Age or developmental stage: Eight Grade/Sophomore Year in Taiwanese Junior High

Harte, J. (2010). The influence of houseplants in a child development center on young children's directed attention.

Harte addresses how houseplants influence children. It was focused on the attention rates, attention state, and adaptive behavior of children. It was focused on increasing the potential learning environment for children and if that could happen with house plants. The methods used involved analyzing and measuring relationships between preschoolers and houseplants. A quasi-experimental observational study was conducted on preschoolers. Observations were recorded and measured on time spent in the area, attention spans, and adaptive behavior of the children. The thesis found that in the study that those who participated in the area between six and eleven times there was a medium effect of houseplants on the time spent there. There were small effects on attention for alert and divided attention

and almost medium effects for sustained and focused attention it was found that for some children, the plants may have influenced them to stay at the sensory bins longer when compared to not having plants in the classroom.[200]

Publication type: Paper
Study type: Thesis
Sample: 1
Duration: Cross-sectional, Longitudinal, Six to Seven Times
Age or developmental stage: Young Children

Ko, H., Schiavon, S., Zhang, H., Graham, L. T., Brager, G., Mauss, I., & Lin, Y.-W. (2020). *The impact of a view from a window on thermal comfort, emotion, and cognitive performance*. https://doi.org/10.1016/j.buildenv.2020.106779

In this study they explored the impact of having or not having a window on thermal perceptions, emotion, and cognitive performance. The study uses a randomized crossover experimental set up with a sample of 86 graduate and undergraduate students. They placed the participants in a room with windows and a room without windows at 28 °C for 2 hours. During this time the participants developed a survey, a creativity test, a cognitive test and a second survey during each hour. All the participants experienced the two conditions during one hour of the experiment. To measure the outcomes of the experiment, they used physical measurements, skin temperature measurements, thermal perceptions, and cognitive performance tests. They found the thermal sensations were significantly cooler in the space with a window compared to the space without a window. Also, 12% more of the participants where thermally comfortable. Memory and the ability to concentrate were higher in the space with a window. They found no significant differences in short term memory, planning, and creativity performance between the 2 conditions. [201]

Publication type: Journal article
Study type: Experimental study
Sample: 86
Duration: 2 hours
Age or developmental stage: college graduates and undergraduates

Lassonde, K. A., Gloth, C. A., & Borchert, K. (2012). Windowless Classrooms or a Virtual Window World: Does a Creative Classroom Environment Help or Hinder Attention? *Teaching of Psychology*, 39(4), 262–267. https://doi.org/10.1177/0098628312456618

Lassonde, Gloth, and Borchert address how creating a view for students of virtual windows affect attentional tasks. The study involved forty undergraduates and they took the Trail Making Task and Benton's Controlled Oral Word Association Test. They were in classrooms with blind-covered windows or virtual windows of nature scenes. They were randomly assigned to one of the two classrooms with twenty in one and twenty in the other. The virtual windows were installed in a basement classroom. The study found that the results of the students on the Trail Making task and Benton's Controlled Oral Word Association Test were affected positively in the classrooms with the virtual windows. Students were found to have a positive influence on

their completion of the tasks. The study also found that students were more efficient on the Trail Making Tasks in the virtual window classroom compared to the no window classroom. The study found that virtual windows were not a distraction in the classroom. The study also found that virtual windows had a positive effect on performance. [202]

Publication type: Journal Article
Study type: Case Study
Sample: 40
Duration: Single Point in Time
Age or developmental stage: Undergraduate

Li, D., & Sullivan, W. C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning,* 148, 149–158. https://doi.org/10.1016/j.landurbplan.2015.12.015

Dongying and Sullivan investigated how nature and greenspaces can help a student with their stress levels. The authors hypothesize that the students view out on to green landscapes can help with their mental fatigue and stress. They conducted a randomized controlled experiment with 94 high school students distributed in 5 high schools. The students were then randomly placed in three room types, no window, window without a good view, and a window with a view to lush vegetation. They measured attentional functioning through digital span, and physiological stress using a set of physiological measurement (body temperature, skin conductance, and heart rate), as well as questionnaires to assess subjective perceptions of stress and attention. They found that students with the view to lush vegetation had significantly increased their recovery from stressful situations, as well as their attention. [203]

Publication type: Journal article
Study type: Experimental study
Sample: 94 high school students, 5 high schools
Duration: 45 minutes, one time
Age or developmental stage: high school students

Lindemann-Matthies, P., Benkowitz, D., & Hellinger, F. (2021). Associations between the naturalness of window and interior classroom views, subjective well-being of primary school children and their performance in an attention and concentration test. *Landscape and Urban Planning*, 214, 104-146. https://doi.org/10.1016/j.landurbplan.2021.104146

Authors address primary students' subjective well-being and performance are affected by the naturalness of window and interior classroom view. The study involved 785 students in the fourth grade. The students were ages eight to eleven years old and their well-being was passed with a written survey. The survey was about their satisfaction, comfort, ability to concentrate, ability to learn, satisfaction with achievements, perceived stress, and social belonging in school. The study found that the students reported less stress and were more focused when they were in a classroom with more natural views. The study also found that there was a positive association between students' connection to nature, which was their time spent in nature, and on plant care, and with their feelings of comfort and learning satisfaction. The more time that students spent in nature created less fatigue and stress for

them and allowed them to pay more attention during lessons. [204]

Publication type: Journal article
Study type: Cross-sectional Study
Sample: 785 students
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Fourth Grade

Mcsweeney, J., Rainham, D., Johnson, S. A., Sherry, S. B., & Singleton, J. (2015). Indoor nature exposure (INE): a health-promotion framework. Health promotion international, 30(1), 126–139. https://doi.org/10.1093/heapro/dau081

Mcsweeney, Rainham, Johnson, Sherry, and Singleton address nature-based spaces and their impact on physiological and psychological health and how indoor nature exposure affects people. The study involved a scoping method that considered a variety of evidence and identified it. The assessment involved the biological, psychological, physical, and social components of health with adults and pediatrics to understand the impact. There were 4,573 articles read with 51 meetings the entire criteria. The study found that indoor nature exposure can promote health and be a tool to do so because of the nature based-stimuli and its interaction with individual characteristics. The study also found that indoor nature exposure research is not always consistent and there are issues with definitions and methodology. Indoor nature exposure may be able to create a built environment that supports our health in all aspects of people's lives. Indoor spaces that are rich with nature may be an effective way of embracing indoor and outdoor health. [205]

Publication type: Journal Article
Study type: Literature Review/Case Study
Sample: 51
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Adults and Pediatrics

Studente, S., Seppala, N., & Sadowska, N. (2016). Facilitating creative thinking in the classroom: investigating the effects of plants and the colour green on visual and verbal creativity. *Thinking Skills and Creativity*, 19, 1-8. https://doi.org/10.1016/j.tsc.2015.09.001

Studente, Seppala, and Sadowska address how students are affected by views of nature the color green, and exposure to live plants. The study included 108 business students in a British University that were randomly assigned one of the three conditions, nature views, the color green, and exposure to live plants. The control group did not have any plants in the classroom space and the second experimental group included a classroom with live plants and large classroom windows that allowed views of nature. The study found that there was increased visual creativity when there was access for students to plants, the color green, and natural views. The study also found that there was no impact on verbal creativity with those three different conditions. The study found that visual creativity can increase with the access to natural greenery and understood that this may not be able to be accommodated by everyone, so with the addition of green colored paper, there were similar effects on visual creativity shown. [206]

Publication type: Journal Article
Study type: Literature Review/Case Study
Sample: 108
Duration: Cross-sectional, Longitudinal
Age or developmental stage: University

Taylor, A. F., Kuo, F. E., & Sullivan, W. C. (2002). Views of nature and self-discipline: Evidence from inner city children. *Journal of Environmental Psychology*, 22(1-2), 49-63. https://doi.org/10.1006/jevp.2001.0241

Taylor, Kuo, and Sullivan address how inner-city children are affected by nature views. The study involved 169 boys and girls. The boys and girls were in 12 high-rise buildings that were architecturally identical. The buildings had varying amounts of nature nearby. The parent ratings of the naturalness of the views were considered to predict how students would perform on tests. Measures were taken on the performance of children on concentration, impulse inhibition, and delay of gratification tests. The study found that girls were affected more by immediate nature views than boys and view accounted for 20% of the variance in scores for them. The study also showed that boys may be affected by distant green spaces as they are used to the green spaces that are near their homes more than the girls. The study also found that girls need to have immediate green spaces near their homes as it can allow them to live more effective, self-disciplined lives. [207]

Publication type: Journal article
Study type: Case Study
Sample: 169 boys and girls
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Boys and Girls, Children

van den Berg, A. E., Wesselius, J. E., Maas, J., & Tanja-Dijkstra, K. (2017). Green Walls for a Restorative Classroom Environment: A Controlled Evaluation Study. *Environment and Behavior*, 49(7), 791–813. https://doi.org/10.1177/0013916516667976

Van den Berg, Wesselius, Maas, and Tanja-Dijkstra address how green walls with living plants affect two elementary schools with a project design, measurements, and follow-ups. Specifically, children's cognitive performance, classroom evaluations, and well-being of children were reported. The study involved 170 elementary school children at two elementary schools in controlled, prospective designed environments with baseline measurements taken. There were also follow-ups are taken at two and four months. Children's cognitive performance was measured with attentional tests and self-report questions to also understand well-being and classroom evaluations. The study found that when there was a green wall placed in four classrooms, the students in those classrooms performed better on tests on selective attention. Children's classroom evaluations were positively affected by the green walls. Children's self-reported well-being was not found to have a measurable effect because of the green wall. The study overall found that a green wall could affect students and create a restrictive classroom design. [208]

Publication type: Journal Article
Study type: Controlled Evaluation Study

Sample: 170
Duration: Cross-sectional, Longitudinal, Two Months
Age or developmental stage: Elementary

Acoustics

Amlani, A. M., & Russo, T. A. (2016). Negative effect of acoustic panels on listening effort in a classroom environment. *Journal of the American Academy of Audiology*, 27(10), 805–815. https://doi.org/10.3766/jaaa.15096

This study examines the impact of acoustic panels on listening tasks in classrooms with 27 third graders, 8 to 9 years old (12 males and 15 females) The panels were analyzed with and without the transmission of a standardized target signal at different positions with also the Speech Transmission Index and how third graders with normal hearing are affected at different positions. Students were given a list of ten monosyllabic words with multiple lists and asked to repeat the words. Then, students were shown random string, single digits before being given the monosyllabic words. Then, students were asked to recall the string of five digits exactly as how they were listed. The experimental study found that as the distance to the signal increased there was a decrease in digit-recall and word recognition. [209]

Publication type: Journal article
Study type: Experimental Study
Sample: 27
Duration: Longitudinal
Age or developmental stage: 3rd Grade

Astolfi, A., & Pellerey, F. (2008). Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. *The Journal of the Acoustical Society of America*, 123(1), 163–173. https://doi.org/10.1121/1.2816563

This study examines the acoustical and environmental quality of 51 secondary-school classrooms. Eight of the classrooms were measured acoustically and a few were acoustically renovated. A questionnaire was given to 1006 students about their perceived visual and acoustical quality based on thermal, indoor air, visual quality, and acoustical quality. Students viewed acoustical and visual quality had the largest impact on their performance in school. There was dissatisfaction regarding indoor air quality, thermal, and acoustics with acoustics being the most relevant. The study also found that there was a correlation between acoustical quality and speech comprehension, with speech comprehension being correlated to speech transmission index. In the classrooms that were nonrenovated, there was a lower satisfaction acoustically. Poor acoustics were found to lead to a decrease in concentration. The study also found that students were more affected by intermittent noise than constant noise. [210]

Publication type: Journal article
Study type: Case Study/Literature Review
Sample: 51
Duration: One Point in Time
Age or developmental stage: Secondary School

Astolfi, A., Bottalico, P., & Barbato, G. (2012). Subjective and objective speech intelligibility investigations in primary school classrooms. *The Journal of the Acoustical Society of America*, 131(1), 247–257. https://doi.org/10.1121/1.3662060

This study examines speech intelligibility and acoustical treatments takes primary schools with 983 students, 7 to 10 years old, in grades 2-5, who were tested using diagnostic time tests and the scores were correlated with the Speech Transmission Index (STI). The classroom's RT was tested before and after the treatment. The study found that 2nd graders, in the lower STI range, understood fewer words than the students in other grades. The study found the most interfering noise was traffic noise, there was a decrease in RT from 1.6 to 0.4 seconds, and that caused the speech score to increase with speech-to-noise level differences. When there was babble noise, there was a similar decrease in RT times that also lead to a speech intelligibility score that had a similar speech-to-noise average range. [211]

Publication type: Journal article
Study type: Case Study
Sample: 983
Duration: Longitudinal, 45 minutes before and after treatment
Age or developmental stage: 2nd to 5th Grade

Astolfi, A., Puglisi, G. E., Murgia, S., Minelli, G., Pellerey, F., Prato, A., & Sacco, T. (2019). Influence of Classroom Acoustics on Noise Disturbance and Well-Being for First Graders. *Frontiers in Psychology*, 10. https://doi.org/10.3389/fpsyg.2019.02736

Astolfi, Puglisi, Murgia, Minelli, Pellerey, Prato, and Sacco piloted a study on noise exposure or excessive reverberation affects the well-being of children at school at a young age and how well they are aware of noise disturbance. The study involved 330 students, 6 to 7 years old, from twenty classes in ten primary schools in Torino, Italy. A questionnaire was about happiness, self-esteem, emotional health, relationships at home and with friends, how much they enjoyed school, noise distance due to different sounds and intensities, and the quality of voices. The study found that long reverberation times cause students to feel unhappy about themselves, complained in classrooms with poor acoustics or about trying to fit in at school. [212]

Publication type: Journal article
Study type: Pilot Study
Sample: 330 Students
Duration: Longitudinal
Age or developmental stage: Primary

Belojevic, G., Evans, G. W., Paunovic, K., & Jakovljevic, B. (2012). Traffic noise and executive functioning in urban primary school children: The moderating role of gender. *Journal of Environmental Psychology*, 32(4), 337–341. https://doi.org/10.1016/j.jenvp.2012.05.005

Traffic noise and student executive functioning (EF) were studied with 311 children in Belgrade, ages 7 to 11 years old; 165 girls and 146 boys living near the center of the city. Teachers were tasked with rating the executive functioning of students by studying and evaluating their independent work and to see how they can follow directions. School noise exposure was measured on three different days. The study found that there were no significant effects of noise levels of ambient noise on executive functioning. The study also found that there was a significant relationship between boys' executive functioning and adverse noise impacts. Chronic noise may damage voluntary control over executive functioning under certain scenarios. Noise abatement policies are proposed to help schools improve education and learning on children's executive functioning. [213]

Publication type: Journal article
Study type: Case Study
Sample: 311
Duration: Longitudinal, 3 days
Age or developmental stage: Seven to 11 Years Old

Berg, F. S., Blair, J. C., & Benson, P. V. (1996). Classroom acoustics: The problem, impact, and solution. Language, Speech, and Hearing Services in Schools, 27(1), 16–20. https://doi.org/10.1044/0161-1461.2701.16

This article is a proposal that addresses classrooms acoustics and the impacts on teachers and students and suggests four solutions to address acoustical problems. The proposal includes literature reviews, experimental articles, case studies, qualitative research papers, and the authors' work to show the problem and how to solve it. The proposal improvements for acoustics in a classrooms: use of sound field amplification systems, noise control, signal control without amplification, and the use of individual amplification systems. The study concludes that poor acoustics in classrooms degrade speech signals. This can lead to an increase in off-topic behavior and lead to problems in teacher's voices and fatigue. Learning is impaired due to poor acoustical environments. [214]

Publication type: Journal article
Study type: Proposal
Sample: NA
Duration: Longitudinal/Cross-Sectional
Age or developmental stage: NA

Bradley, J. S., & Sato, H. (2008). The intelligibility of speech in elementary school classrooms. *The Journal of the Acoustical Society of America*, 123(4), 2078–2086. https://doi.org/10.1121/1.2839285

Speech intelligibility in 41 elementary school classrooms at 12 schools with. 1st, 3rd, and the graders, ages 6, 8, and 11 years old, was studied using speech intelligibility tests while being seated at normal desks in their normal

classrooms. The study found that the average intelligibility scores were related to the grade of the student and the signal-to-noise ratio. The study also found that there is a major difference between laboratory studies and in real classroom studies. The results mainly found that +15 dB signal-to-noise ratio is not a good learning environment for the youngest children. The study also found that they can estimate ideal acoustical criteria for elementary school classrooms by coking all the speech intelligibility test results, noise levels during teaching situations, and measurements of speech. [215]

Publication type: Journal article
Study type: 2nd Part of Experimental Study
Sample: 41 classrooms of 6-, 8-, and 11-year-old
Duration: Single Point in Time
Age or developmental stage: Six, Eight, Eleven Years Old

Brammer, A., & Laroche, C. (2012). Noise and communication: A three-year update. *Noise and Health*, 14(61), 281–281. https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=14631741&v=2.1&it=r&id=GALE%7CA314191886&sid=googleScholar&linkaccess=fulltext

This is a three-year update and literature review on how noise impacts all jobs, professions, people no matter what age, and specifically classrooms. It includes information that classrooms have had re-evaluations of the acoustical conditions that are acceptable for education. The review points out that children need a larger speech signal-to-noise ratio (SNR) than adults. A recent study examined low predictability and high predictability in normal-hearing children where there were clusters, yet the clusters depending on the type of signal-to-noise ratio they require. The review also found that teachers have serious health effects in classrooms with high noise levels. [216]

Publication type: Journal article
Study type: Literature Review Update
Sample: NA
Duration: Longitudinal/Cross-Sectional
Age or developmental stage: Children to Adult

Buchari, & Matondang, N. (2017). The impact of noise level on students' learning performance at state elementary school in Medan. AIP Conference Proceedings, 1855. https://doi.org/10.1063/1.4985498

This study examines noise levels on learning performance of elementary school students in Medan, Indonesia. The study was observed at State Elementary School in Medan, Indonesia. The study measured the Threshold Limit Value (TLV) at 24 different locations and found that the standard TLV of >55 dBA was exceeded – a regulation made by the Decree of the Minister of Environment. Based on the Noise Mapping, the study found that there were different noisy zones. There was the Yellow Zone with the level of 65-69 dBA and there was the Red Zone which was 69-75 dBA. Students reported that they felt dizzy at 22% because of the noise, felt uncomfortable at 21%, felt like they could not understand their teacher at 22% and students' performances decreased by 22%. The teachers suggested that to reduce the noise levels, acoustical materials in and out of the classroom should be used. [217]

Publication type: Journal article
Study type: Case Study
Sample: 1, 24
Duration: Single Point in Time
Age or developmental stage: Elementary

Caviola, S., Visentin, C., Borella, E., Mammarella, I., & Prodi, N. (2021). Out of the noise: Effects of sound environment on maths performance in middle-school students. *Journal of Environmental Psychology*, 73(May 2020), 101552. https://doi.org/10.1016/j.jenvp.2021.101552

The purpose of this study was to see how background noise affected learning and academic achievement, specifically on math exams and learning. The study involved 162 students ages eleven to thirteen years old who were given a math test with calculation problems. The acoustical conditions were categorized in three categories: quiet, traffic, or classroom noise because most urban schools experience these conditions. Students who were younger, performed poorly in classrooms with noisy conditions. These differences disappeared with older students. Younger children are likely more impacted by noise or poor acoustical conditions than older children. The study also showed that difficult tasks will be affected by any sound in a learning environment as it breaks focus and concentration. [218]

Publication type: Journal article
Study type: Case Study
Sample: 162 11 to 13 Year Old's
Duration: Longitudinal
Age or developmental stage: 11- to 13-Year-Old

Choi, C. Y., & McPherson, B. (2005). Noise levels in Hong Kong Primary Schools: Implications for classroom listening. *International Journal of Disability, Development and Education*, 52(4), 345–360. https://doi.org/10.1080/10349120500348714

Choi and McPherson examined noise levels in 47 primary school classrooms in Hong Kong, along with the ambient noise level and speech intensity of students and teachers. Acoustical treatments and amplification systems were also documented in the study to address similarities and differences. The study found that the average noise level in a classroom while occupied was 60.74 dB (A). The average unamplified speech-to-noise ratios of teachers were 13.53 dB and the amplified speech-to-noise ratio was 18.45 dB. of teachers. The unamplified speech-to-noise ratio was 4.13 dB for students. The study also found that most classrooms did not provide sufficient acoustical treatments. The listening conditions were not optimal for learning, and it was recommended that sound-field amplification systems should be used to improve listening conditions for students and teachers in these classrooms. [219]

Publication type: Journal article
Study type: Case Study
Sample: 47
Duration: Single Point in Time
Age or developmental stage: Primary

Clark, C. (2012). A 3 year update on the influence of noise on performance and behavior. *Noise and Health*, 14(61), 292–292. https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=14631741&v=2.1&it=r&id=GALE%7CA314191888&sid=googleScholar&linkaccess=fulltext

This is a three-year update and a literature review on the influence of noise exposure in children's environments, focusing on noise effects on children's cognition and experimental studies of auditory distraction. The review addresses research that shows exposure-effect thresholds, classroom acoustics and learning, and how to create the best environment. The study includes research, case studies, experiments, and literature reviews. There are two types of auditory distractions: those that interrupt processes those that interfere with processes. The ones that interrupt processes impair memory capability, while the ones interfere processes do not impair memory capability. The literature review also concluded that more research is needed in this area. [220]

Publication type: Journal article
Study type: Literature Review Update
Sample: NA
Duration: Longitudinal/Cross-Sectional
Age or developmental stage: Elementary Students to Secondary

Connolly, D., Dockrell, J., Shield, B., Conetta, R., & Cox, T. (2013). Adolescents' perceptions of their school's acoustic environment: The development of an evidence-based questionnaire. *Noise and Health*, 15(65), 269–269. https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=14631741&v=2.1&it=r&id=GALE%7CA335874169&sid=googleScholar&linkaccess=fulltext

This study examined perceptions of 2,588 English students ages eleven to sixteen years old about their school acoustical environment via an online questionnaire. The factors that were addressed: the ease of hearing at school, sensitivity to noise, problems that occur in the classroom because of noise, and annoyance with the intermittent noise. Responses showed that students who had hearing impairments, were learning English, or had additional learning support were more affected than other students. Older students were more annoyed by the noise and had significant learning impairments compared to younger students. Students that were in open-plan classrooms or attending schools with external noise were less positive about school. [221]

Publication type: Journal article
Study type: Case Study/Questionnaire
Sample: 2,588 Students
Duration: Longitudinal/Cross-Sectional
Age or developmental stage: Elementary to High School

Connolly, D. M., Dockrell, J. E., Shield, B. M., Conetta, R., & Cox, T. J. (2015). Students' perceptions of school acoustics and the impact of noise on teaching and learning in secondary schools: Findings of a questionnaire survey. *Energy Procedia*, 78, 3114–3119. https://doi.org/10.1016/j.egypro.2015.11.766

Using a questionnaire survey, this study examined students' perceptions

of school acoustics environment and the impact of noise on teaching and learning with adolescents. 2,588 students from six different schools aged 11 to 16 years old took an online questionnaire with 93 questions. Students with hearing impairments, spoke English as a second language, or needed more learning supporting to meet their needs were more affected by the acoustics in schools compared to students who did not need additional learning support. Students in schools that had cellular classrooms without other noise sources saw their school acoustics in a more positive light than students who had open plan classrooms or had more external noise sources. [222]

Publication type: Journal article
Study type: Experimental Study/Questionnaire
Sample: 2,588
Duration: Single Moment in Time
Age or developmental stage: 11-16 Years Old

Connolly, D., Dockrell, J., Shield, B., Conetta, R., Mydlarz, C., & Cox, T. (2019). The effects of classroom noise on the reading comprehension of adolescents. *The Journal of the Acoustical Society of America*, 145(1), 372–381. https://doi.org/10.1121/1.5087126

Connolly, Dockrell, Shield, Conetta, Mydlarz, and Cox conducted a study on the impact that the noise on reading and vocabulary-learning tasks of adolescents. The study involved 976 English high school students. They were given laptops to complete reading tasks while experiencing different noise levels of classrooms through headphones. The questions were multiple-choice about comprehension and word learning. The number of questions attempted, how long it took to complete, and answers were all recorded. The conditions were at 50 and 70 dB L(Aeq) and 50 and 64 dB L(Aeq). The study found that students' performances significantly decreased at the 70 dB L(Aeq) condition, also for the accuracy of answers to fact-based and word learning questions and number of questions attempted. The noise levels at 64 dB L(Aeq) had a detrimental effect on the older students. [223]

Publication type: Journal article
Study type: Case Study
Sample: 976
Duration: Longitudinal
Age or developmental stage: High School

Dockrell, J. E., & Shield, B. (2004). Children's perceptions of their acoustic environment at school and at home. *The Journal of the Acoustical Society of America*, 115(6), 2964–2973. https://doi.org/10.1121/1.1652610

This study examines children's perceptions of their acoustical environment at home and at school with 2,036 children completing a questionnaire about noise sources at home and school, their level of annoyance by these noise sources, and their ability to discriminate different classroom listening conditions. Teachers also completed a questionnaire about noise sources in their classrooms. It was found that children are sensitive to their noise environments and are good judges of their environment. Older students could hear better in all conditions when they could see their teacher. Younger

children performed better than older children when there was background babble from other children on the playground outside. Older children may be more affected by speech-like interference. Younger children are sometimes faced in different ways which makes hearing and listening harder if they can't face or see their children. Younger children repeated a greater difficulty hearing the children in the same situations as older children. [224]

Publication type: Journal article
Study type: Questionnaire survey
Sample: 2,036
Duration: Single Point in TIme
Age or developmental stage: Primary

Dockrell, J. E., & Shield, B. M. (2006). Acoustical barriers in classrooms: The impact of noise on performance in the classroom. *British Educational Research Journal*, 32(3), 509–525. https://doi.org/10.1080/01411920600635494

Primary school children (158 in year 3) in six classrooms were studied to determine impact of classroom noise on speed and literacy tasks. Three noise conditions were randomly assigned to the classrooms: babble, babble plus environment noise, and babble and environmental. The study found that there was a differing type of negative effect of noise depending on the task that was observed. The study also found that children performed significantly better in the base and babble conditions on speed professing tasks compared to the significantly worse performance of children in the babble and noise environment condition. The study also found that only in the babble condition, children performed significantly worse on the verbal tasks. Children with special education needs were also negatively affected in the babble condition of noise in a different way. [225]

Publication type: Journal article
Study type: Case Study
Sample: 158
Duration: Single Point in Time
Age or developmental stage: Year 3 Primary School

Dockrell, J. E., & Shield, B. (2012). The impact of sound-field systems on learning and attention in elementary school classrooms. *Journal of Speech, Language, and Hearing Research*, 55(4), 1163–1176. https://doi.org/10.1044/1092-4388(2011/11-0026)

This study examined the impacts on learning and attention using sound-field systems in elementary school classrooms. The study involved 458 elementary students. Questionnaire surveys were given to teachers and students, acoustical surveys conducted of classroom conditions, and students tested with and without the sound-field systems. Data collected over six months of student perceptions, changes in performance on academic and cognitive tests, all with amplification, were collection. Teachers believed students performed better, had better listening conditions, and paid more attention to verbal instructions with the sound-field systems. The sound-field systems increased the performance of students on a nonverbal measure of speed processing. They also increased the performance on listening comprehension. This showed that amplified classrooms created an

environment that students performed better when their original classroom conditions were poorer acoustically. [226]

Publication type: Journal article
Study type: Case Study
Sample: 458 Elementary Students
Duration: Longitudinal
Age or developmental stage: Elementary Students

Eru, R. H., Truchon, C., Sy, G., & Bilodeau, A. (1990). Problems of Noise in School Settings: A Review of Literature and the Results of an Exploratory Study Problemes de bruit en milieu seo/sire: etst des eonnsisssnees et etude exp/orstoire. In *JSLPAIROA* (Vol. 4, Issue 3).

Noise in Quebec elementary and high school settings is examined regarding how students and teachers are affected by noise. Authors conducted an exploratory study using a questionnaire survey to teachers that showed that they consider noise to be detrimental. Physical measurements were taken in 50 classrooms at six different elementary schools. Measurements were also taken during 35 gym classes in four different elementary schools and four different high schools. Authors found that reverberation time and background noise in classrooms are not optimal conditions for speech intelligibility. The plans with the most acoustical problems are open-planned schools and classrooms that do not have sound-absorbing surfaces or do not have insulation. A large area of concern is in school gymnasiums where physical education suffers because of the acoustical conditions. [227]

Publication type: Journal article
Study type: Literature Review
Sample: 50
Duration: Cross-sectional, Single Point in Time
Age or developmental stage: Elementary and High School

Evans, G. W., & Lepore, S. J. (1993). Nonauditory Effects of Noise on Children: A Critical Review. In *Environments* (Vol. 10, Issue 1). https://about.jstor.org/terms

This study examined nonauditory effects of noise on children. The literature review included studies, essays, experiments, and factors such as memory, attention, perception, emotional effects, motivational effects, and physiological effects and how children are affected by noise. Health issues were found involving elevated blood pressure, deficits in reading, and attentional deficits that come from chronic exposure to noise that causes potential long-term issues. The review also finds lowered motivation, auditory discrimination, along with shifts in resistance to distraction, definitions in cognitive development for infants, and a worsening memory with processing demands from chronic noise exposure. There are many shortcomings in the existing work on nonauditory effects. There is a lack of developmental analyses, temporal parameters, age effects, children's mobility, and noise at home leads to the conclusion of the need for more studies to understand children's health because of noise. [228]

Publication type: Journal article
Study type: Literature Review

Sample: 50
Duration: Cross-sectional
Age or developmental stage: 1 to 14 Years Old

Evans, G. W., & Maxwell, L. (1997). Chronic noise exposure and reading deficits: The mediating effects of language acquisition. *Environment and Behavior*, 29(5), 638–656. https://doi.org/10.1177/0013916597295003

This study examines the learning and educational deficits of chronic aircraft noise exposure and speech perception on 116 first and second graders from two elementary schools in New York. The "noise" school was near the New York metropolitan airport and the control school was located in a quiet neighborhood. The study found that the children exposed to chronic aircraft noise, had learning deficits in reading even when taking the tests in quiet conditions. The study also found that there is evidence that language acquisition is also impacted by chronic noise and those exposed chronically have impaired speech perception. The study also found partial support for the belief that ambient noise exposure impairs speech perception and that means that speech mediates relationships between acquiring reading skills and noise exposure. [229]

Publication type: Journal article
Study type: Case Study
Sample: 116
Duration: Longitudinal, 24 hours, 20 minutes
Age or developmental stage: 8 to 11 Years Old

Gheller, F., Lovo, E., Arsie, A., & Bovo, R. (2020). Classroom acoustics: Listening problems in children. *Building Acoustics*, 27(1), 47–59. https://doi.org/10.1177/1351010X19886035

Gheller, Lovo, Arise, and Bovo examine the impacts of acoustics in classrooms on listening skills and learning in children. The study includes a literature review, peer-reviewed articles, and experimental studies on classroom acoustics and effects on primary school children's listening and how they perform. The primary focus was on background noise and the reverberation time in classrooms. {ermanent exposure to listening conditions that are not correct or unsafe will destroy a child's learning experience and strain their effort to comprehend. Background noise and reverberation have the most significant effect on children. Younger children have more trouble blocking out the noise than older children. There are guidelines to be followed, yet not many classrooms follow the acoustic levels. By using sound-absorbing panels on walls or ceiling and walls and an amplification system could lead to better results. [230]

Publication type: Journal article
Study type: Case Study/Review
Sample: NA
Duration: Cross-Sectional
Age or developmental stage: Primary

Haines, M. M., Stansfeld, S. A., Job, R. F. S., Berglund, B., & Head, J. (2001). Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine*, 31(2), 265–277. https://doi.org/10.1017/S0033291701003282

Haines, Stansfeld, Job, Berglung, and Head study chronic noise exposure on mental health and cognitive function in 340 children, ages 8 to 11 years old. The noise exposure is due to proximity to London Heathrow Airport. Students were tested on their cognitive performance due to their proximity to high aircraft noise areas, and then compared with children that attended four matched control schools with lower levels of aircraft noises. Cognitive and mental health test were administered to them at school and salivary cortisol was measured in a subsample of children. The study found that higher aircraft noise annoyance was associated with chronic aircraft noise exposure. It also causes poorer reading comprehension measured by standardized scales with adjustments for other factors. The learning issues caused by chronic aircraft exposure cause stress and worsened cognitive performance for young school children. [231]

Publication type: Journal article
Study type: Case Study
Sample: 340
Duration: Longitudinal, 3 days
Age or developmental stage: 8 to 11 Years Old

Hygge, S. (2003). Classroom experiments on the effects of different noise sources and sound levels on long-term recall and recognition in children. *Applied Cognitive Psychology*, 17(8), 895–914. https://doi.org/10.1002/acp.926

This study tested the recall and recognition of noise experiments with 1,358 children, ages twelve to fourteen years old and their ability to remember, store information, and then recall that information. Students took ten different noise experiments in their normal classrooms and then were asked to recall and recognize a text one week later on a test. Sources of noise were aircraft and road traffic noise at 55 dBA Leq and signal and combined noise sources for fifteen minutes at 66 dBA Leq. The study found that there was a strong effect that noise played on recall and significant effect on recognition. Aircraft noise combined with train or road traffic greatly interfered with recognition and recall. The study also found that distraction, perceived effort, perceived difficulty, and arousal did not mean automatic effects on recognition and recall. [232]

Publication type: Journal article
Study type: Case Study
Sample: 1,358
Duration: Longitudinal, one week
Age or developmental stage: 12 to 14 Years Old

Iannace, G., Sicurella, F., Colamesta, P., & Gentilin, M. (2018). Acoustic project of a conference room of the secondary school "Avenir 33" (Delémont, Switzerland). In *Canadian Acoustics - Acoustique Canadienne* (Vol. 46, Issue 2). https://www.researchgate.net/publication/325976838

A conference room at a secondary school in Switzerland is analyzed for room shape, materials, acoustical treatments might make the best speech intelligibility for students, and to find the best areas to place acoustical treatments. A simulation was run repeatedly with Odeon software to analyze and connect acoustical indicators for the room. The proposed conditions with the optimal acoustical environment were found to be about 1.0 seconds for the reverberation times in the conference room. The study found that when there was an inclusion of reflective and sound-absorbing wooden panels, there was a better acoustical condition in the conference room. The study also found that by using a software and testing spaces, the ability to create the best acoustical environment for different purposes is possible. [233]

Publication type: Journal article
Study type: Case Study
Sample: 1
Duration: Single Point in Time
Age or developmental stage: Secondary

Jablonska, J. (2021). Architectural acoustics and speech legibility in university environment – Case study. *Applied Acoustics*, 177, 107917. https://doi.org/10.1016/j.apacoust.2021.107917

In this case study, examines the relationship between acoustical comfort and architecture and tests using reverberation time (RT) and against the standards. A solution is tested by covering a wall and part of a ceiling. This allows for acoustical comfort and architectural design with multiple geometries. The findings also point out that there data from Polish Norm PN-B-02151–4 shows the relationship of space volume and appropriate RT. This is important because if there is a guideline to follow, the question is why people are not following it. The case study also finds that every room needs to test its acoustic absorbance to create a healthy learning space for students and teachers. [234]

Publication type: Journal article
Study type: Case study
Sample: One university classroom
Duration: Longitudinal,
Age or developmental stage: University

Johansson, E., Vigertsson, D., & Morris, D. (2017). How Children Perceive the Acoustic Environment of Their School. Noise and Health, 19(87), 84–84. https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=14631741&v=2.1&it=r&id=GALE%7CA490669514&sid=googleScholar&linkaccess=fulltext

This study compares the results of an evidence-based questionnaire given to 149 Swedish children ages nine to thirteen children asking their views and perceptions of their acoustical environment in school. The dining hall

and corridors between classrooms were found to have the worst conditions for listening to and understanding peers and teachers. Students were most annoyed with noise during tests and reading times. The next highest annoyance was noise from other students in the classroom and traffic noise. Noise was most detrimental to learning during verbal processing. [235]

Publication type: Journal article
Study type: Case Study
Sample: 149
Duration: Longitudinal
Age or developmental stage: 9–13

Kanakri, S. M., Shepley, M., Tassinary, L. G., Varni, J. W., & Fawaz, H. M. (2017). An Observational Study of Classroom Acoustical Design and Repetitive Behaviors in Children With Autism. *Environment and Behavior*, 49(8), 847–873. https://doi.org/10.1177/0013916516669389

Kanakri, Shepley, Tassinary, Varni, and Fawaz conducted a study on the acoustical impact of school classrooms on children with autism. The methods included empirical research an observational experiment. The research showed how interior spaces' characteristics can help support and develop the learning environment for children with autism. Behavior occurrences and associated sound levels were compared using Noldus Observer XT software. There was a correlation between the frequency of target behaviors and noise levels. When sound levels increase, several observed behaviors occurred such as hitting, loud vocalizations, increased blinking, verbal complaints, repetitive motor movements, and repetitive speech. The authors also believe that understanding the built environment in terms of autism is a public health consideration. [236]

Publication type: Journal article
Study type: Case Study
Sample: 20
Duration: Longitudinal
Age or developmental stage: 6 to 9 Years Old

Klatte, M., Meis, M., Sukowski, H., & Schick, A. (2007). Effects of irrelevant speech and traffic noise on speech perception and cognitive performance in elementary school children. *Noise and Health*, 9(36), 64–64. https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=14631741&v=2.1&it=r&id=GALE%7CA171523140&sid=googleScholar&link-access=fulltext

Klatte, Meis, Sukowski, and Schick investigate how noise from traffic and background/irrelevant speech impacts elementary school children, specifically on cognitive tests and speech perception. The methods included moderate intensity of background noise that was tested on children six to eight years old about their short-term storage and verbal information processing abilities. Two groups of first graders were tested by pictures of words that sounded similar. The serial recall of information that was verbalized towards the children was disrupted by the Danish speech acting as background noise. Competing oral instructions, the memory of hearing things that were not words, and categorizing what kind of speech sounds were heard were

also greatly affected by the background noise. Children were unable to store and process verbal information because of background noise that they could not understand. The quality of sound is what affects a children's cognitive performance, not the absolute level. [237]

Publication type: Journal article
Study type: Case Study
Sample: 46
Duration: Longitudinal, one month
Age or developmental stage: Second Grade

Klatte, M., Hellbrück, J., Seidel, J., & Leistner, P. (2010). Effects of Classroom Acoustics on Performance and Well-Being in Elementary School Children: A Field Study. *Environment and Behavior*, 42(5), 659–692. https://doi.org/10.1177/0013916509336813

In the field study, authors found that young students in classrooms with long reverberation times could understand more noise-embedded words than in the control room. Also, children performed worse in phonological processing tasks and reported a higher difficulty due to indoor noise and not being able to understand the speech of teachers. These factors show that children are significantly affected in classrooms without proper acoustics and reverberation times. Listening and hearing conditions in classrooms are critical for children's well-being. A child's sense of well-being also decreases if there is high outside noise upon entering the classroom, leading to a sense of poor understanding of classmates, and therefore decreased attentiveness in the classroom. Addressing this issue will lead to environments that create a welcoming and strong learning spaces for children. [238]

Publication type: Journal article
Study type: Field Study
Sample: 487 Students
Duration: Longitudinal
Age or developmental stage: 1st and 2nd Grade Students

Klatte, M., Bergström, K., & Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children. *Frontiers in Psychology*, 4. https://doi.org/10.3389/fpsyg.2013.00578

This literature review addresses how acute and chronic effects of noise exposure impact children's cognitive performance. Children are exposed to these problems, even more, when they are not native speakers of the language spoken at the school or have language or attention disorders. The literature review includes case studies, experimental studies, and quasi-experimental studies to show how children are affected when exposed to acute or chronic noise conditions. Acute exposure has a negative effect on speech perception and listening comprehension. Most impacts are more significant in children than adults. Noise-induced disruption affected tasks that are not auditory. Reverberation and indoor noise in classrooms resulted in poor performance on verbal tasks performed. Aircraft noise that created high exposure environments significantly lowered reading scores. [239]

Publication type: Journal article
Study type: Literature Review
Sample: NA
Duration: Cross-Sectional
Age or developmental stage: Children

Laurìa, A., Secchi, S., & Vessella, L. (2020). Acoustic comfort as a salutogenic resource in learning environments—a proposal for the design of a system to improve the acoustic quality of classrooms. *Sustainability* (Switzerland), 12(22), 1–25. https://doi.org/10.3390/su12229733

Authors address the acoustical issues that students and teachers face in learning spaces, specifically classrooms. The study addresses the concerns that come from too much sound reverberation and poor learning environments. Various types sound-absorbing panels, can alter sound reverberation in classrooms. Different types of panels such as hanging, mounted, or 3D panel elements to increase sound absorption and create healthier learning environments. Too much sound reverberation can impact student learning, but also how teachers interact with their students using sound absorbing panels can enhance learning. The paper also discussed using "acoustic shaped" panels as a part of an overall experience with sound for students. [240]

Publication type: Journal article
Study type: Proposal
Sample: 52 classrooms in Florence, Italy
Duration: Longitudinal
Age or developmental stage: NA

Lercher, P., Evans, G. W., & Meis, M. (2003). Ambient noise and cognitive processes among primary schoolchildren. *Environment and Behavior*, 35(6), 725–735. https://doi.org/10.1177/0013916503256260

This study examines the effects on attention and memory of primary schoolchildren who are chronically exposed to ambient noise levels. The study involved 123 fourth-grade students who were selected based on parental educational level and residential noise. The noise exposure range was where the two socio-demographically homogenous samples differed with one at 46.1 Ldn and the other at 62 Ldn. There was prescreening for hearing loss at a mobile, sound-attenuated laboratory. The study found that there was a significant relationship between chronic noise exposure and intentional and incidental memory. For children who were exposed chronic noise, there was poor recognition memory. There were no effects seen when testing visual search performance because of chronic noise. Ambient noise in typical residential areas will cause problems as young children develop by affected their memory development. Chronic noise exposure can also lead to hearing loss. [241]
Publication type: Journal article
Study type: Case study
Sample: 123
Duration: Longitudinal
Age or developmental stage: 4th Grade

Leung, S. W. H., & McPherson, B. (2006). Classrooms for children with developmental disabilities: Sound-field and public address amplification systems compared. *International Journal of Disability, Development and Education*, 53(3), 287–299. https://doi.org/10.1080/10349120600847508

Leung and McPherson found that special education classrooms in eight primary schools around Hong Kong did not provide correct acoustical conditions for teaching and learning and needed amplification systems. The public announcement (PA) and sound field (SF) amplification systems both met the standards and recommendations set by Sound Noise Reduction standard (SNR) (he EU standard) and ANSI/American Speech-Language-Hearing Association (ASHA). The noise levels of unoccupied classrooms averaged 44dBA, which is 9dBA higher than recommended. These classrooms had no acoustical treatments. The SF system created a more uniform sound, and its average SNR was 4 dBA higher than the PA systems. This means that the SF amplification system created a more effective acoustical space. SF systems can also relate to audio-and-visual equipment, which allows for the inclusion of more things that could be causing problems and then can be fixed. [242]

Publication type: Journal article
Study type: Case Study
Sample: 8 Primary School Classrooms
Duration: Longitudinal
Age or developmental stage: Primary Students

Larsen, J. B., & Blair, J. C. (2008). The effect of classroom amplification on the signal-to-noise ratio in classrooms while class is in session. *Language, Speech, and Hearing Services in Schools*, 39(4), 451–460. https://doi.org/10.1044/0161-1461(2008/07-0032)

Amplification on signal-to-noise ratios in classrooms as classes were in session. The methods involved in this case study were analyzing 5 different elementary classrooms for noise and reverberation times at three different schools. The measurements were taken during class. The noise was measured during activities to compare with sound level measures. No amplification was compared to infrared classroom amplification. The study found that students could hear the teacher's voice at an average of 12 dB above the noise floor when amplification was used. This is much different from an average of +2 dB above the noise floor without amplification. Speech communication increased due to the amplification system. The signal-to-noise ratio also increased when a hand-held microphone combined with the amplification system was used. The study also found that the optimal signal-to-noise ratio was for the front and back of the classrooms when amplification systems were used. [243]

Publication type: Journal article
Study type: Case Study
Sample: 5
Duration: Single Point in Time, Cross-sectional
Age or developmental stage: Elementary

Ljung, R., Sörqvist, P., & Hygge, S. (2009). Effects of road traffic noise and irrelevant speech on children's reading and mathematical performance. *Noise and Health*, 11(45), 194–198. https://doi.org/10.4103/1463-1741.56212

Ljung, Sörqvist, and Hygge examined the effects of road traffic noise and irrelevant speech on 187 children (89 girls and 98 boys), ages 12 to 13 years old from nine schools in a medium-sized city in Sweden. They were given reading comprehension tests, mathematical reasoning problems, and basic mathematics tests. There were three types of classrooms, road traffic noise (N=50), silence (N=70), and irrelevant speech (N=66). The experimental study found that road traffic noise negatively affected the reading speed of students. Road traffic noise also impaired basic mathematics. The study also found that reading comprehension and mathematical reasoning were not affected. The irrelevant speech was found to not disrupt student's performance while completing any of the tests. The study concludes that road traffic noise is disruptive to cognitive performance. [244]

Publication type: Journal article
Study type: Experimental Study
Sample: 187
Duration: Single Point in Time
Age or developmental stage: 12 to 13 Years Old

Manlove, E. E., Frank, T., & Vernon-Feagans, L. (2001). Why should we care about noise in classrooms and child care settings? *Child and Youth Care Forum*, 30(1), 55–64. https://doi.org/10.1023/A:1016663520205

Noise in classrooms and childcare settings examined factors involving noise levels, the pitch of a sound, loudness of sound, reverberation times, children's development based on noise, and movements that can be made. Children in elementary schools and childcare settings are negatively affected by noise. The literature finds that to fix these problems solutions can be having flooring and furnishing that can be easily cleaned and sanitized because that also means they will not have sound-absorbing materials in them. It is also stated that by having "soft" spaces, there will be more things that can absorb sound along with having wall-mounter cork boards and curtains over the windows. The study concludes that those most vulnerable are infants and toddlers and the effects that they face will affect them as they grow and go to school. [245]

Publication type: Journal article
Study type: Literature Review
Sample: NA
Duration: Cross-sectional
Age or developmental stage: Child Care and Elementary

Massonnié, J., Rogers, C. J., Mareschal, D., & Kirkham, N. Z. (2019). Is classroom noise always bad for children? The contribution of age and selective attention to creative performance in noise. *Frontiers in Psychology*, 10(FEB). https://doi.org/10.3389/fpsyg.2019.00381

This study examines the idea that all noise hurts children's learning and looks at the differences in tasks in a quiet and loud room and factors of

age, memory, and selective attention can contribute to the results. Forty-five students, age 11 years old were tested three times individually. Selective attention was tested with Stroop and Franleer test where students indicate which animal was bigger in real life. The Alternative Uses Task was used to compare the results with results with a 2012 study. Students who were ages five to eight years old have low selective attention skills and were more affected by the noise. The study did find that children who had a good selective attention rate were protected against noise and its effects when completing tasks in the quiet and moderate rooms. [246]

Publication type: Journal article
Study type: Experimental Study
Sample: 44
Duration: Single Point in Time (4 times)
Age or developmental stage: 11 Years Old

Massonnié, J., Frasseto, P., Mareschal, D., & Kirkham, N. Z. (2020). Learning in Noisy Classrooms: Children's Reports of Annoyance and Distraction from Noise are Associated with Individual Differences in Mind-Wandering and Switching skills. *Environment and Behavior*. https://doi.org/10.1177/0013916520950277

Massonnié, Frasseto, Mareschal, and Kirkham analyzed acoustics factors and children's responses to noise in a classrooms with 112 children, 8 and 11 years old who were asked questions based on several factors such as hearing difficulties, interference, annoyance from noise attention capture, and perceived classroom loudness. Structural Equation Models were run to differentiate between noise interference and annoyance for each individual child. Children reported that interference and annoyance from noise made it more difficult to hear and switch attention. Children who had previously experienced mind-wandering, felt more interference by noise. [247]

Publication type: Journal article
Study type: Case Study
Sample: 112
Duration: Longitudinal
Age or developmental stage: 8.70 to 11.38 Years Old

Maxwell, L. E., & Evans, G. W. (2000). The effects of noise on pre-school children's pre-reading skills. *Journal of Environmental Psychology*, 20(1), 91–97. https://doi.org/10.1006/jevp.1999.0144

This study examines the effects of chronic noise exposure on children's pre-reading skills with 90 four and five-year-old children. Teachers evaluated their cognitive pre-reading skills and their use of language and their understanding of language. Children were tested in year one and year two before and after the installation of sound-absorbent panels. Children were found to score higher in quieter conditions than in noisier ones when being tested on recognition of letter-number-word measures. These children in the quieter condition had higher scores on the language scale by their teachers. The study also found that students in the quieter classrooms were less suspectable to induced helplessness than the children in the noisy classrooms. [248]

Publication type: Journal article
Study type: Intervention/Case Study
Sample: 90
Duration: Longitudinal, Two Years
Age or developmental stage: 4 to 5 Years Old

Mealings, K. T., Demuth, K., Buchholz, J. M., & Dillon, H. (2015). The effect of different open plan and enclosed classroom acoustic conditions on speech perception in Kindergarten children. *The Journal of the Acoustical Society of America*, 138(4), 2458–2469. https://doi.org/10.1121/1.4931903

The open plan style for classrooms showed learning issues were a result of intrusive noise from other classrooms that disrupted learning. Kindergarten is a foundational time that is a key determinant for success in school. The case study reveals that when adjacent classrooms are engaged in quiet activities, there are acceptable hearing and listening conditions. When sound levels are higher, there is a decrease in speech perception, accuracy, and speed. The new style of open plan classroom is more acceptable than past ones because there was no change in the K-6 classroom despite its larger size, but students performed better in a different environment. The results of the study show that despite the desire for aesthetic value in classrooms, having an open plan style, decreased test scores and reduced sound perception for Kindergarteners. [249]

Publication type: Journal article
Study type: Case Study
Sample: 205 Students
Duration: Longitudinal
Age or developmental stage: Kindergarten Students

Novanta, G. G. R., Garavelli, S. L., & Sampaio, A. L. L. (2020). Is the Level of Noise in a School Environment Harmful to the Hearing of Teachers? *International Archives of Otorhinolaryngology*, 24(4), 503–507. https://doi.org/10.1055/s-0040-1702969

Authors address noise levels in classrooms that cause hearing loss of teachers through measurements of distortion-product otoacoustic emissions (DPOAE), amplitude, and signal-to-noise ratio in classrooms. No correlation was found between DPOAE ratings and teachers' age or experience. There was a significant difference in amplitude of DPOAE when the frequencies of before work and after work were compared at 2 kHz. The average noise level measured in the classroom was 76 dBA, which is 41 dBA more than what is recommended. The study concluded that when the outer hair cells of the Corti organ are damaged, permanent damage can occur over time. The authors understand that poor acoustics can be detrimental to students and also teachers who need to deliver information to their students. [250]

Publication type: Journal article
Study type: Cross-Sectional Study
Sample: 76 Primary School Teachers
Duration: Cross Sectional
Age or developmental stage: Primary school teachers

Nelson, P. B., & Soli, S. (2000). Acoustical barriers to learning: Children at risk in every classroom. *Language, Speech, and Hearing Services in Schools*, 31(4), 356–361. https://doi.org/10.1044/0161-1461.3104.356

This literature review covers acoustical issues in classrooms and children with auditory problems. The literature review included studies, experiments, and conditions that address hearing loss (and minimal hearing loss), as well as learning English as a second language. The review also covers studies that show the educational effects on children. The recommended classroom noise level is approximately 35 dBA and RTs of 0.4-0.6 seconds. There is a significant learning impact on children who differ from some sort of hearing disorder or loss or are trying to learn English. The study concludes that the cost of the best acoustical environment may be great, but the outcomes will be better for everyone. [251]

Publication type: Journal article
Study type: Literature Review
Sample: NA
Duration: Cross-sectional
Age or developmental stage: 5 to 15 Years Old

Nelson, P., Kohnert, K., Sabur, S., & Shaw, D. (2005). Classroom noise and children learning through a second language: Double jeopardy? In *Language, Speech, and Hearing Services in Schools* (Vol. 36, Issue 3, pp. 219–229). https://doi.org/10.1044/0161-1461(2005/022)

This study examined impacts of classroom noise on the attention and speech perception with 22 native Spanish-speaking 2nd graders from three classrooms learning English as compared to English-only-speaking second graders. The first study focused on how children react to on-task behavior with and without a sound field amplification. The second study focused on the effects of noise at +10 dB signal-to-noise ratio during an English word recognition task experiment. The second study found that there was a significant decrease in word recognition in the second language English group and the first language is English groups during the noise. The second study also found there was more of an impact for the second language group. The study also found that children who are learning English as their second language have a large disadvantage over other people while listening with typical noise and reverberation. [252]

Publication type: Journal article
Study type: Case Study
Sample: 22
Duration: Single Moment in Time
Age or developmental stage: 2nd Grade

Osman, H., & Sullivan, J. R. (2014). Children's auditory working memory performance in degraded listening conditions. *Journal of Speech, Language, and Hearing Research*, 57(4), 1503–1511. https://doi.org/10.1044/2014~JSLHR-H-13-0286

This study examines children's auditory performance and listening conditions in 20 children, ages 8 to 10 years old with normal hearing. Is auditory working

memory impacted when there are many babble noises from multiple speakers and when there is a degraded signal-to-noise ratio compared entirely to a quiet condition. Children were tested on their auditory working memory on backward digital recall, listening recall primary, and listening recall secondary. A decrease in children's auditory working memory performance was found when there was babble from multiple speakers noise and noise. When children were given tests that involved a greater amount of memory storage and processing demands, they performed poorly. Every task was negatively impacted by noise. The study concludes that multi-talker babble noise harms the auditory working memory of children. [253]

Publication type: Journal article
Study type: Case Study
Sample: 20
Duration: Single Point in Time
Age or developmental stage: 8 to 10 Years Old

Pääkkönen, R., Vehviläinen, T., Jokitulppo, J., Niemi, O., Nenonen, S., & Vinha, J. (2015). Acoustics and new learning environment - A case study. *Applied Acoustics*, 100, 74–78. https://doi.org/10.1016/j.apacoust.2015.07.001

The study examined acoustic performance in classrooms and corridors at the Oulu Normal School in Finland. Measurements were made of several factors such as, clarity, spreading attenuation, disturbance radius, using the Speech Transmission Index, Rapid Speech Transmission Index, Finnish guidelines, and International Standards Organization. There was good acoustical quality found in the classrooms for both setup situations. The study also found that the acoustical performance of corridor areas with soft carpet were usable for educational purposes. The study also found that the background noise and sound insulation levels did not meet the Finnish Standards guidelines. [254]

Publication type: Journal article
Study type: Case Study
Sample: 1 School
Duration: Longitudinal, 2 Years
Age or developmental stage: Middle School

Pelegrín-García, D., Brunskog, J., & Rasmussen, B. (2014). Speaker-oriented classroom acoustics design guidelines in the context of current regulations in European countries. *Acta Acustica United with Acustica*, 100(6), 1073–1089. https://doi.org/10.3813/AAA.918787

The focus of this study is on speaker-oriented classroom acoustics design guidelines (speech intelligibility and reducing noise levels) and health implications on teachers and cognitive impairments on students in European countries. There were two-room acoustic parameters with the voice support (ST(v)), linked to vocal effort, and the decay time (DT(40, ME)) derived from an oral-binaural impulse response, all linked to vocal comfort. The literature review found that the average reverberation times in classrooms should be between 0.45 s and 0.6 s for flexible teaching methods in classrooms that have a volume less than 210 m~3 and forty students. Larger classrooms need to have specific studies to analyze the best materials, geometry, and speaker/audience placements to help the voice and learning for students.

The literature review also addresses how European countries differ in their requirements. [255]

Publication type: Journal article
Study type: Literature Review/Proposal
Sample: 150
Duration: Longitudinal
Age or developmental stage: School Children

Peng, J., Lau, S. K., & Zhao, Y. (2020). Comparative study of acoustical indices and speech perception of students in two primary school classrooms with an acoustical treatment. *Applied Acoustics*, 164. https://doi.org/10.1016/j.apacoust.2020.107297

Peng, Lau, and Zhao conducted a comparative and intervention study on subjective speech perception of students before and after an acoustical treatment. Two classrooms were chosen in primary schools in Guangzhou, China. The classrooms used six different listening positions that were measured using the swept-frequency method. The RT, early-to-late sound energy ratio and speech transition were measured. A questionnaire was administered with 11 questions to forty-four 3rd-grade students in classroom A and forty-three 3rd grade students in classroom B. The acoustical treatment was completed with sound absorption materials installed on the ceilings. The results showed that the RT time was reduced, and the early-to-late speech ratio and speech transmission increased. The survey showed that most students liked the classrooms more after the acoustical treatment. The teachers' voices were reported to be much clearer. [256]

Publication type: Journal article
Study type: Comparative and Intervention Study
Sample: 73
Duration: Longitudinal
Age or developmental stage: 3rd and 4th Graders

Picard, M., & Bradley, J. S. (2001). Revisiting speech interference in classrooms. In *International Journal of Audiology* (Vol. 40, Issue 5, pp. 221–244). https://doi.org/10.3109/00206090109073117

This review of literature examines ambient noise and reverberation time and on speech intelligibility in classrooms. The literature review includes factors that involve noise levels, speech perception, poor acoustics, hearing impaired and non-hearing impaired students, acoustic performance, and guidelines for measuring noise levels and acoustics. It was found that classrooms with poor acoustics is the most significant condition for both hearing impaired students and non-hearing impaired students with ambient noise levels at 4-37 dB above the current "optimal" understanding. The review also found that younger students, ages 10 to 11 should have noise levels ranging from 39 dBA, and for 6-7-year-olds only 28.5 dBA. For teens, 12 years old and older, and young adults, ambient noise cannot exceed 40 dBA, and reverberation times of 0.5s are the most optimal conditions. [257]

Publication type: Journal article

Study type: Literature Review
Sample: About 350
Duration: Cross-sectional
Age or developmental stage: 5 to 18 Years Old

Pirilä, S., Jokitulppo, J., Niemitalo-Haapola, E., Yliherva, A., & Rantala, L. (2020). Teachers' and Children's Experiences after an Acoustic Intervention and a Noise-Controlling Workshop in Two Elementary Classrooms. *Folia Phoniatrica et Logopaedica*, 72(6), 454–463. https://doi.org/10.1159/000503231

In this study, teachers and students experienced an acoustical intervention at their school. The study improved the acoustical listening experience for the students, as well as an improved experience for teachers making it easier for talking, communicating, and teaching. Two teachers and 50 elementary students were given questionnaires after the interventions. The students reported that they found their teachers' voices to be clearer and more audible after the interventions and reacted positively to the acoustical intervention. It was also found that students twelve to thirteen years old were annoyed by sounds more than those eight to nine years old. The study concludes that there is an ability to improve listening conditions and voice ergonomics for individuals. [258]

Publication type: Journal article
Study type: Case Study
Sample: 2 Primary School Teachers and 50 Elementary Students
Duration: Longitudinal
Age or developmental stage: Primary

Prodi, N., Visentin, C., & Feletti, A. (2013). On the perception of speech in primary school classrooms: Ranking of noise interference and of age influence. *The Journal of the Acoustical Society of America*, 133(1), 255–268. https://doi.org/10.1121/1.4770259

Seven classrooms in six primary schools were examined for noise interference and speech using specific combinations of intelligibility and perception. The designs of the rooms were similar and there was no acoustical treatment in any classroom. Classroom volumes ranged from 121 to 187 m^3. Classrooms were divided into four areas and measurement positions were placed in each one. A Diagnostic Rhyme Test (DRT) where words are phonetically balanced and consist of pairs of rhyming words. The case study found that with joint babble and activity noise there is a more negative effect on performance. The noise sound field mixed with typical disturbances and then mixed with the teacher's voices were analyzed. The study also found that younger students are more affected by extra-acoustics. [259]

Publication type: Journal article
Study type: Case Study
Sample: 7 classrooms
Duration: Single Point in Time (4 times)
Age or developmental stage: Primary

Prodi, N., & Visentin, C. (2015). Listening efficiency during lessons under various types of noise. *The Journal of the Acoustical Society of Americ*a, 138(4), 2438–2448. https://doi.org/10.1121/1.4932053

Listening efficiency of under exposure to different types of noises was examined in 33 classes with 530 students, ages 8 – 10 years old using the Speech Transmission Index (STI). Italian primary-aged students were analyzed on their ability to do well on intelligibility, response time and their ratio, and their "listening efficiency". The Diagnostic Rhyme Test was given to them with pairs of consonant-vowel-consonant vowel rhyming words. The study found that students respond differently to noise throughout an activity. The study also found that the results in the speech perception are horrible when there is traffic and babble noise in the background compared to tapping noise in better listening conditions. The study concludes that skills that come with age may be affected differently when hearing traffic and tapping noise versus babble noise. [260]

Publication type: Journal article
Study type: Case Study
Sample: 530
Duration: Single Point in Time
Age or developmental stage: Eight to Ten Years Old

Puglisi, G. E., Prato, A., Sacco, T., & Astolfi, A. (2018). Influence of classroom acoustics on the reading speed: A case study on Italian second-graders. *The Journal of the Acoustical Society of America*, 144(2), EL144–EL149. https://doi.org/10.1121/1.5051050

This study examines acoustical conditions in noisy and reverberant classrooms and literacy development and speech communication with 94 second graders at an Italian primary school. The schools selected for the study were had similar socioeconomic status. The reverberation times (RT) were measured at the end of the year in rooms that had only desks, chairs, and shelves. The reading tests given were designed for the specific study and were based on standards. The case study found that speech clarity was significantly correlated with reading tasks. A classroom that can support speech clarity and decrease reverberation times can have diffusive and absorptive surfaces. If the clarity of speech was high, the test scores were higher, and if the speech clarity was low, the scores were also lower. [261]

Publication type: Journal article
Study type: Case Study
Sample: 94
Duration: Longitudinal, one year
Age or developmental stage: 2nd Grade

Riley, K. G., & McGregor, K. K. (2012). Noise hampers children's expressive word learning. *Language, Speech, and Hearing Services in Schools*, 43(3), 325–337. https://doi.org/10.1044/0161-1461(2012/11-0053)

This study examines the effects of noise on speech style and learning with thirty-one children ages 9 to 11 years old. The signal-to-noise ratio and speech style is modified so that half of the children hear words with white

noise and half hear them hear without white noise. The study found that children who were exposed to quiet conditions learned to produce the words more accurately than those in the noise conditions. The "plain" speech had fewer accurate words than "clear" speech no matter what condition. [262]

Publication type: Journal article
Study type: Experimental Review
Sample: 31 Children
Duration: Longitudinal
Age or developmental stage: 9 to 11 Years Old

Ronsse, L. M., & Wang, L. M. (2013). Relationships between unoccupied classroom acoustical conditions and elementary student achievement measured in eastern Nebraska. *The Journal of the Acoustical Society of America*, 133(3), 1480–1495. https://doi.org/10.1121/1.4789356

This study examined classroom acoustical conditions and student achievement with 34 third-grade classrooms and 33 fifth-grade classrooms in Nebraska public schools. The background noise levels (BNL) and reverberation times of unoccupied rooms were gathered and achievement scores of students collected. Higher BNLs in unoccupied rooms showed a decrease in the scores for student reading and language subject areas. Unoccupied BNLS should be less than 45 dBA for the best performance. The study also found that there is a high correlation between those who receive reduced or free lunch to achievement than BNLs. When controlling demographics, the case study found that students had higher language scores when they were in classrooms with lower distortion of frequency-smoothed magnitude values. [263]

Publication type: Journal article
Study type: Case Study
Sample: 67
Duration: Single Point in Time
Age or developmental stage: 3rd and 5th Grade

Rudner, M., Lyberg-Åhlander, V., Brännström, J., Nirme, J., Pichora-Fuller, M. K., & Sahlén, B. (2018). Listening comprehension and listening effort in the primary school classroom. *Frontiers in Psychology*, 9(JUN). https://doi.org/10.3389/fpsyg.2018.01193

This study examinies listening comprehension and listening effort in primary schools with the goal of determining whether the combined effects of background noise, voice quality, and visual cues impact listening. The study involved 245 students, age eight years old. Listening conditions in classrooms were simulated using a digitally animated speaker with a house voice and the background noise was babbled by several children talking at once. The results of this study show that even with low levels of babble background noise, there is an interference with listening comprehension and that this effect may reduce if the student can see the speaker's face. The results showed that multiple factors combined to create changes in listening comprehension and efforts for those in primary school. [264]

Publication type: Journal article

Study type: Experimental Study
Sample: 245
Duration: Single point in time
Age or developmental stage: 8 Years Old

Russo, D., & Ruggiero, A. (2019). Choice of the optimal acoustic design of a school classroom and experimental verification. *Applied Acoustics*, 146, 280–287. https://doi.org/10.1016/j.apacoust.2018.11.019

Russo and Ruggiero examine the optimum acoustical configuration of a classroom, by analyzing three commonly used classroom designs in Italian state schools. The reverberation time, index of clarity of the word, and speech transmission index, UNI 11367, and integrated impulse response (ISO 3382) were used. The classrooms were measured, tested, and analyzed to find the most favorable one and how to achieve similar acoustical spaces in other classrooms. The improved acoustic environment was achieved with sound-absorbent panels placed on ceilings and walls. The four common materials used were investigated based on their behavior with absorption, frequency, and antibacterial-fireproofing. The design made is meant to be used by acoustic engineers in classrooms to create the best spaces for learning, retaining material, attention, speech recognition, and reading scores. [265]

Publication type: Journal article
Study type: Case Study
Sample: Three Classrooms
Duration: Cross-Sectional
Age or developmental stage: NA

Sala, E., & Rantala, L. (2016). Acoustics and activity noise in school classrooms in Finland. *Applied Acoustics*, 114, 252–259. https://doi.org/10.1016/j.apacoust.2016.08.009

The study involved 40 elementary classrooms involved from fourteen different schools in Finland to determine the impact of classroom noise levels on learning, speech production, and perception. Noise levels were measured during teaching hours. Background noise was caused by plumbing, heating, electrical applications, and ventilation. The results found only a few classrooms had acceptable acoustical design under Finnish guidelines. None of the classrooms passed the Speech Transmission Index. Background noise was too high in most of the classrooms and disrupted learning. Noises during activities were also too high and disrupted listening and communication. The results show major risks for occupational voice disorders. Poor acoustical issues can create learning and communication problems. [266]

Publication type: Journal article
Study type: Case Study
Sample: 40 Elementary Classrooms
Duration: Single Point in Time
Age or developmental stage: Elementary

Sato, H., & Bradley, J. S. (2008). Evaluation of acoustical conditions for speech communication in working elementary school classrooms. *The Journal of the Acoustical Society of America*, 123(4), 2064–2077. https://doi.org/10.1121/1.2839283

This study examines the acoustical conditions for speech communication in 41 elementary classrooms in Ottawa, Canada. Acoustical quality for speech communication and the conditions of the rooms were studied during teaching activities. Twenty-seven of the 41 rooms were rectangularly shaped. The study found that students experienced teachers speaking at around 60.4 dBA and an average speech-to-noise ratio of 11 dBA during activities. The study found that even if students are well-behaved, they were still the cause of the most dominant sources of noise. Fixing this problem needs to be focused on reducing sound levels from students arriving late and by positioning them father away from the group, initially. [267]

Publication type: Journal article
Study type: Case Study
Sample: 41
Duration: Single Point in Time
Age or developmental stage: Elementary

Scannell, L., Hodgson, M., García Moreno Villarreal, J., & Gifford, R. (2016). The Role of Acoustics in the Perceived Suitability of, and Well-Being in, Informal Learning Spaces. *Environment and Behavior*, 48(6), 769–795. https://doi.org/10.1177/0013916514567127

Scannell, Hodgson, Villarreal, and Gifford address the acoustical issues that come from informal learning spaces. Their case study addresses material, ventilation systems, perception of acoustics, shared learning spaces compared to closed or open learning spaces, well-being of 850 students, and the measured sound levels in spaces. These results show that people prefer spaces with softer materials, density may be the largest acoustical issue, and that background sound in unoccupied spaces is detrimental. The well-being of a student is impacted in spaces where they spend more time.[268]

Publication type: Journal article
Study type: Case Study
Sample: 850 Post-secondary Students
Duration: Longitudinal
Age or developmental stage: Post-secondary education

Secchi, S., Astolfi, A., Calosso, G., Casini, D., Cellai, G., Scamoni, F., Scrosati, C., & Shtrepi, L. (2017). Effect of outdoor noise and façade sound insulation on indoor acoustic environment of Italian schools. *Applied Acoustics*, 126, 120–130. https://doi.org/10.1016/j.apacoust.2017.05.023

This study took place in 100 Italian schools from nursery to upper secondary schools examining traffic and facade sound insulation impacts on noise levels and speech intelligibility in classrooms. Reverberation time was measured in each classroom. Outdoor noise levels were also measured along with the age and characteristics of facades. The study found that a correlation between the year of construction and the main characteristic of the facade and the facade

sound insulation. There was a decrease in indoor sound pressure level due to traffic noise with improvements of the facade acoustic insulation. Indoor surfaces need to be analyzed in the future to improve speech intelligibility and reduce internal reverberation time. [269]

Publication type: Journal article
Study type: Case Study/Cross Sectional
Sample: 100
Duration: Longitudinal
Age or developmental stage: Nursery to Upper Secondary

Shield, B. M., & Dockrell, J. E. (2003). The effects of noise on children at school: A review. In *Building Acoustics* (Vol. 10, Issue 2, pp. 97–116). SAGE Publications UK: London, England. https://doi.org/10.1260/135101003768965960

This study examines the effects of noise on children at school. Noise includes classroom noise levels, academic performance, annoyance, and environmental noise effects. The literature includes past texts, articles, case studies, experiments, and factors that involve speech intelligibility, children's understanding of speech, sources of noise, general effects of noise, environmental noise effects, effects of classrooms noise, children's perception of noise, noise levels, and the current standard for classroom acoustics. The review found that noise does have an effect on the performance of children at school. Older children in the primary age group were found to suffer from the noise the most. The majority of children stated that they were annoyed by noise at school. When the classrooms were measured, those without acoustical treatment had the highest level of noise and this may be because they had the highest level of activity. A cause of noise that can seriously harm learning is the degradation of speech intelligibility in the classroom. [270]

Publication type: Journal article
Study type: Literature Review
Sample: 97
Duration: Cross-sectional
Age or developmental stage: Primary, 5 to 11 Years Old

Shield, B. M., & Dockrell, J. E. (2008). The effects of environmental and classroom noise on the academic attainments of primary school children. *The Journal of the Acoustical Society of America,* 123(1), 133–144. https://doi.org/10.1121/1.2812596

This study examines the impacts of environmental and classroom noise on primary school students in London and Wales, ages seven to eleven years old. Data examined included academic standardized tests of literacy, mathematics, and science. Physical sound measurements were taken both inside and outside of the classrooms where students were taking the tests. The study found that external noise impacted the older children more than the younger children. It was also found that individual external events have large impacts on performance scores. There was a negative relationship between performance and noise levels even after the results were corrected depending on socio-economic factors. The results of the study show that test scores of the standardized test are greatly affected by noise in the classroom and the increase in background noise can have a negative effect on scores.

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Publication type: Journal article
Study type: Case Study
Sample: 29,900
Duration: Longitudinal, Cross-Sectional
Age or developmental stage: Elementary

Siebein, G. W., Gold, M. A., Siebein, G. W., & Ermann, M. G. (2000). Ten ways to provide a high-quality acoustical environment in schools. *Language, Speech, and Hearing Services in Schools*, 31(4), 376–384. https://doi.org/10.1044/0161-1461.3104.376

Authors discuss the ten recommendations for high quality acoustical environment for school classrooms in Florida. Fifty-six actual classrooms were measured for their reverberation time, background noise, and impulse response techniques. Air-conditioning systems and noise control techniques should be implemented to control interference. Construction materials and assemblies, as well as site selection and design with the use of a room amplification system need to be considered. An acoustical consultant and audiologist need to be involved in the process. The ceiling height needs to be limited and sound-absorbing surfaces need to be added. Carpet needs to be installed and furniture arrangement should reduce the distance between students and their teacher. [272]

Publication type: Journal article
Study type: Clinical Forum
Sample: 56
Duration: Longitudinal, 3 days
Age or developmental stage: Kindergarten to High School

Smaldino, J. J., & Crandell, C. C. (2000). Classroom amplification technology: Theory and practice. *Language, Speech, and Hearing Services in Schools*, 31(4), 371–375. https://doi.org/10.1044/0161-1461.3104.371

Smaldino and Crandell address acoustics for students with hearing loss and without hearing loss and how sound amplification systems can help them. A literature review about acoustics, sound amplification systems, results on reverberation times, and listening. There was information addressing acoustical standards, classroom modifications, challenges from modifications, and personal amplification devices. The clinical forum found that good classroom design can be made because of amplification technology and improve listening conditions for everyone. Specifically, hearing aids will also benefit children with hearing loss, but hearing aids also do not fully address signal-to-noise ratios at this time. Personal SNR-enhancing systems may benefit children with greater hearing loss and classroom speakers will benefit signal-to-noise ratios for children with normal or almost-normal hearing. Children benefited from sound amplification systems, but now must learn to use them. Teachers must also learn how to use them and figure out what system or systems work best for their classrooms. [273]

Publication type: Journal article
Study type: Clinical Forum

Sample: NA
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Day Care to Higher Education

Spratford, M., Walker, E. A., & McCreery, R. W. (2019). Use of an application to verify classroom acoustic recommendations for children who are hard of hearing in a general education setting. *American Journal of Audiology*, 28(4), 927–934. https://doi.org/10.1044/2019~AJA-19-0041

This study examines how children who are hard of hearing are impacted by noise and reverberation using a smartphone app. The study took place in 164 classrooms with 1st, 2nd, and 4th graders. Two research questions were proposed: How reliable are acoustic measurements collected using an iOS device, application, and external microphone? What proportion of classrooms meet the American National Standards Institute's standards for unoccupied noise levels and reverberation? A smartphone application was used to measure clarity, reverberation, and sound levels. The smartphone app was found to be reliable source in measuring classroom acoustics. The study also found that all the classrooms in the study exceeded noise levels recommended by the American National Standards Institute's advocated guide. The classrooms did meet the reverberation time recommendation. The study found that children who are hard of hearing suffer more because of the learning environments. The research purposes that the App may be a cost-effective way to measure and monitor acoustics in classrooms. [274]

Publication type: Journal article
Study type: Research Study
Sample: 164
Duration: Single Moment in TIme
Age or developmental stage: 1st, 3rd, 4th Grade

Sullivan, J. R., Osman, H., & Schafer, E. C. (2015). The effect of noise on the relationship between auditory working memory and comprehension in school-age children. *Journal of Speech, Language, and Hearing Research*, 58(3), 1043–1051. https://doi.org/10.1044/2015~JSLHR-H-14-0204

Auditory comprehension and the effects of noise was studied in children ages eight to ten years old with normal hearing. They were given comprehension and working memory tests in a noise and quiet environment. The study found that in a noise environment, there was significant poor performance on comprehension and auditory working memory tests compared to a quiet environment. The tests that involved details, understanding, vocabulary, and reasoning was more significant in the noise environment ($p<.05$). School-age children's comprehension and auditory working memory, in the noise environment, are negatively affected. If there are degraded listening conditions, attention is taken away from a primary task because working memory is strongly related to the performance on comprehension tests in noise environments. [275]

Publication type: Journal article
Study type: Case Study
Sample: 20

Duration: Single Point in Time
Age or developmental stage: 8 to 10 Years Old

Valente, D. L., Plevinsky, H. M., Franco, J. M., Heinrichs-Graham, E. C., & Lewis, D. E. (2012). Experimental investigation of the effects of the acoustical conditions in a simulated classroom on speech recognition and learning in children. *The Journal of the Acoustical Society of America*, 131(1), 232–246. https://doi.org/10.1121/1.3662059

Valente, Plevinsky, Franco, Heinrichs-Graham, and Lewis study the abilities and performance of elementary school children on speech-perception and intelligibility tasks in a simulation. The simulated classroom measured the comprehensive performance of a discussion and a lecture in four different environments. The environments varied in RT and background noise levels. The RT was either 0.6 or 1.5 s and the signal-to-noise level was either +10 or +7 dB. Performance was also compared to adult subjects. Increasing background noise and reverberation caused a decrease in performance on comprehension tasks. However, there was a minimal difference in measures of sentence recognition. The decrease in these scores meant an environment was created that did not allow for the correct learning situations that students could be in or situations that teachers could be in that would produce successful results. [276]

Publication type: Journal article
Study type: Experimental Study
Sample: 3 Children and 3 Adults
Duration: Single Point in Time
Age or developmental stage: Elementary

Van Kempen, E., Van Kamp, I., Lebret, E., Lammers, J., Emmen, H., & Stansfeld, S. (2010). Neurobehavioral effects of transportation noise in primary schoolchildren: A cross-sectional study. *Environmental Health: A Global Access Science Source*, 9(1). https://doi.org/10.1186/1476-069X-9-25

This study examines road traffic noise and aircraft noise exposure on 553 primary students, ages 9 to 11 years old, near the Schiphol Amsterdam Airport at twenty-four primary schools. The NES, Neurobehavioral Evaluation System, was used as well as paper tests. The case study found that during the Switching Attention Test (SAT) children made significantly more mistakes if they attended schools with higher aircraft and road noise levels. The study also found that there is coherence with the tests given about neurobehavioral and paper-and-pencil tests that are very high due to a factor structure and correlational pattern. The study concludes that children are affected more at school due to noise when trying to complete a complex test or task compared to when they are trying to do simples ones.[277]

Publication type: Journal article
Study type: Case Study
Sample: 553
Duration: Single Point in Time
Age or developmental stage: Primary

Wålinder, R., Gunnarsson, K., Runeson, R., & Smedje, G. (2007). Physiological and psychological stress reactions in relation to classroom noise. Scandinavian Journal of Work, *Environment and Health*, 33(4), 260–266. https://doi.org/10.5271/sjweh.1141

This study tests the hypothesis that classroom noise is related to stress reactions in Sweden at three elementary school classrooms with 10 year old students in the fourth grade. Factors examined were systolic blood pressure, reduced diurnal cortisol, indicators of emotional distress, and headaches and fatigue. The equivalent sound levels (Leq) were measured daily over four weeks from September to December. Students answered questionnaires about symptoms and disturbances. In the first and last week, the children performed standardized drawing tests that showed emotional indicators. The study found that the daily Leq during the school day was 59 to 87 dB(A). Their sound levels led to an increased in symptoms relating to fatigue, headaches, and reduced diurnal cortisol variability. The Swedish classrooms' average sound levels seem to have a negative health impact and that can indirectly or directly be related to stress reactions in children. [278]

Publication type: Journal article
Study type: Case Study
Sample: Three classrooms of students
Duration: Longitudinal, 4 weeks
Age or developmental stage: 4th Grade

Waye, K. P., Magnusson, L., Fredriksson, S., & Croy, I. (2015). A screening approach for classroom acoustics using web-based listening tests and subjective ratings. *PLoS ONE*, 10(1). https://doi.org/10.1371/journal.pone.0116572

This study examines a web-based screening approach for classroom acoustics with listening tests and questionnaires involving 1,106 students from fifty-nine classes and thirty-eight schools. Students were ages 13-19. The primary focus on the study was students' comprehension of speech, their feelings about their acoustic environment, and the acoustics of the classroom. There was a high background noise level, low background noise level, close position to a loudspeaker, and far position to a loudspeaker. There was also a questionnaire given to the students. In 88% of the classrooms, at least one student reported that they had problems concentrating because of the noise. In 69% of the classes, there were three or more students who stated that the sound environment in their classrooms was adverse. The study also found that background noise level and distance to the loudspeaker had a large influence on student's comprehension of speech. [279]

Publication type: Journal article
Study type: Research Article/Case Study
Sample: 1106
Duration: Single Point in Time
Age or developmental stage: 13 to 19 Years Old

Whitlock, J. A. T., & Dodd, G. (2008). Speech intelligibility in classrooms: Specific acoustical needs for primary school children. *Building Acoustics*, 15(1), 35–47. https://doi.org/10.1260/135101008784050223

Speech intelligibility in classrooms is largely based on background noise

levels, RT, and early decay times. Ten classrooms with ages 12 to 13 years old were tested in Ottawa, Canada. The classrooms chosen had the widest ranges of acoustical conditions. A Fairbanks rhyme test was given where students what to understand what was saying while playing recorded speech at four different levels with a loudspeaker at the front of the classroom. Optimum reverberation times in classrooms are from about 0.4 seconds to 0.5 seconds which is much shorter than what is considered to be standard. The results of this study showed that the ideal design for acoustical conditions is either in terms of the combinations of the reverberation time and background noise level or the 50-ms useful/detrimental ratios. [280]

Publication type: Journal article
Study type: Case Study
Sample: 10 classrooms
Duration: Single Point in Time (4 times)
Age or developmental stage: 12 to 13 Years Old

Wilson, W. J., Marinac, J., Pitty, K., & Burrows, C. (2011). The use of sound-field amplification devices in different types of classrooms. *Language, Speech, and Hearing Services in Schools*, 42(4), 395–407. https://doi.org/10.1044/0161-1461(2011/09-0080)

This study examines the of sound-field amplification (SFA) in different types of classrooms with 147 students, ages eight years old (70 females and 78 males) and their performance at beginning and end of the second semester during their third year in primary school. The study took place in Brisbane, Australia and each school had two classrooms participating where one had an SFA device and one without one. The study found that SFA devices caused small, yet significant improvements in the listening abilities of students. Sound-field amplification devices also improved auditory analysis skills. The improvements only happened in brick buildings compared to demountable buildings that had solid walls between classrooms compared to open spaces. The study also found that classrooms with better acoustics will bring better results when adding SFA devices. [281]

Publication type: Journal article
Study type: Report on Case Study
Sample: 147
Duration: Longitudinal, Start and End of 1 Semester
Age or developmental stage: Eight Years Old

Yang, W., & Bradley, J. S. (2009). Effects of room acoustics on the intelligibility of speech in classrooms for young children. *The Journal of the Acoustical Society of America*, 125(2), 922–933. https://doi.org/10.1121/1.3058900

Speech intelligibility and impacts on learning in elementary school classrooms were examined in 1st, 3rd, and 6th grade classroom with 6-, 8-, and 11-year-old students. The participants were given speech tests that were recorded binaurally before in an imitated classroom condition and then put into headphones. The simulated conditions in the classrooms involved early-to-late arriving sound ratios and differing reverberation times. The study

found that intelligibility scores increased as reverberation times decreased with a constant signal-to-noise ratio. Intelligibility scores were almost as high as they could be for multiple RT when conditions like increasing speech level with the varied reverberation time, at a constant noise level. The study found that the intelligibility scores of young children increased when sound that was added was early reflections of speech sounds. [282]

Publication type: Journal article
Study type: Experimental Study
Sample: 217
Duration: Longitudinal, two times a year
Age or developmental stage: 6 to 11 Years Old

Connection to the outdoors, outdoor learning, physical activity

Becker, C., Lauterbach, G., Spengler, S., Dettweiler, U., & Mess, F. (2017). Effects of Regular Classes in Outdoor Education Settings: A Systematic Review on Students' Learning, Social and Health Dimensions. *International Journal of Environmental Research and Public Health*, 14(5), 485. https://doi.org/10.3390/ijerph14050485

Becker, Lauterbach, Spengler, Dettweiler, and Mess address the benefits of Outdoor Education Programmes and discuss the benefits they have on students. The systematic review consisted of using online databases that involved German and English-language journal articles that were peer-reviewed. Reviewers then screened the studies to assess the methodological quality. The studies were about curriculum and school-based Outdoor Education Programmes and the academic, personal, and social development of students, along with physical activity. The review found that in the thirteen studies chosen for analysis about social, learning, and additional outcomes of Outdoor Education Programmes. The majority of the studies reported positive effects. The physical, academic, social, and psychological dimensions were found to be promoted by compulsory school- and curriculum-based Outdoor Education Programmes. The study recommends that further studies be done on mental health and physical activity and the effects that Outdoor Education Programmes have on them.[283]

Publication type: Journal article
Study type: Systemic Review
Sample: 13
Duration: Cross-sectional
Age or developmental stage: Preschool to Secondary

Browning, M., & Rigolon, A. (2019). School Green Space and Its Impact on Academic Performance: A Systematic Literature Review. *International Journal of Environmental Research and Public Health*, 16(3), 429. https://doi.org/10.3390/ijerph16030429

Browning and Rigolon address how green spaces in school affect and impact

academic performance. Specifically, how and if green spaces and academic performances are tied together. The review included 13 peer-reviewed articles that were about green spaces, types of green spaces, distances of green spaces from schools, and academic outcomes. There were 112 findings reported in the thirteen articles. Specifically, there were measurements of performance on different types of tests and how views, location, size, and distance from greenery affected students' well-being and performance. The review found positive results that were round showed that tree, cover, greenness, and green land cover up to 2,000 meters from schools. There was also a positive association for grades, at the end of the semester, and college preparatory exams when compared to math or reading scores. Views of greenery from classroom windows improve the concentration of students. The review also found that the view of greenery also reduces self-reported stress and heart rate levels. [284]

Publication type: Journal Article
Study type: Systemic Literature Review
Sample: 13
Duration: Cross-sectional, Longitudinal, 1 Semester
Age or developmental stage: Primary to High School

Donovan, G. H., Michael, Y. L., Gatziolis, D., & Hoyer, R. W. (2020). The Relationship Between the Natural Environment and Individual-Level Academic Performance in Portland, Oregon. *Environment and Behavior*, 52(2), 164–186. https://doi.org/10.1177/0013916518796885

Donovan, Michael, Gatziolis, and Hoyer address how students' abilities to perform on an academic level are affected by their connection to the natural environment. The study involved 17,918 students from Portland, Oregon for the math model and 19,459 students for the reading model. The study involved math tests and reading tests that measured their ability to academically perform. The study measured the distance tree cover was to a child's home and how that affected their performance on the reading and math tests. The study found that a 1-standard deviation increase of the tree cover caused a move for children from the 50th percentile to the 51 percentile for the math tests when trees were in 200 m of a child's home. The study also found that there was also an increase from the 50th percentile to the 56th perception on reading tests when there was a 1-standard deviation increase in the covering of trees from 100 meters of a home. [285]

Publication type: Journal Article
Study type: Research Study
Sample: 37,377 students
Duration: Cross-sectional, Longitudinal, 1 Year
Age or developmental stage: Grades 3 through 8, and 11

Ebbeck, M., Yim, H.Y.B. & Warrier, S. Early Childhood Teachers' Views and Teaching Practices in Outdoor Play with Young Children in Singapore. *Early Childhood Educ J* 47, 265–273 (2019). https://doi.org/10.1007/s10643-018-00924-2

Ebbeck, Yim, and Warrier address how outdoor play influences young children and what teachers and educators believe about playtime outdoors and that includes the outdoor environment and access to it. The research paper measured children's development because of outdoor play, outdoor play space in urban areas, and outdoor play in childcare settings. were measured and analyzed in the texts studied and analyzed. 432 teachers were involved and were early childhood educators. The study found that teachers support outdoor play and time spent outside. Most teachers believed that it influenced children's holistic development. It also was a positive activity for teachers as it motivated more children, interested them, and allowed for more enjoyment for them. Challenges were stated by teachers about the outdoor environment, location, size, and safety of children. The study purposes that nature walks may also be used, photographs should be taken of the environments, and open spaces should be researched. Portable equipment is also recommended as it could be sued in and outside of the classroom. [286]

Publication type: Journal Article
Study type: Research Paper
Sample: 432
Duration: Cross-sectional, Single Point in Time
Age or developmental stage: Early Childhood Education

Fjørtoft, I. (2004). Landscape as Playscape: The Effects of Natural Environments on Children's Play and Motor Development. Children, *Youth and Environment*, 14(2), 21–44. http://www.colorado.edu/journals/cye/

Fjørtoft addresses how students are impacted by the natural environment when they play in it and how their play and motor skills develop. The methods involved in this quasi-experimental study were 75 kindergarteners in three kindergartens. The group's backgrounds were compared as well as the similarities between playground equipment. The study measured with a pre-test and then nine months later, a post-test in the following year. There were experimental and control groups and the tests students were given included balance, speed, flexibility, and strength tests. The study was analyzed and compared to understand how the landscape affected children. The study found that children showed an increase that was statistically significant in motor fitness when they were provided with space to play that was a natural landscape. The study also found that there were significant differences in the control and experimental groups. The experimental groups showed that there was an increase in coordination and balance compared to the control group. [287]

Publication type: Paper
Study type: Quasi-experimental Study
Sample: 75 students, two groups
Duration: Cross-sectional, Longitudinal, nine months
Age or developmental stage: Kindergarten

Gilavand, A., Espidkar, F., & Gilavand, M. (2016). Investigating the impact of schools' open space on learning and educational achievement of elementary students. *International Journal of Pediatrics, 4(4), 1663–1670.* https://doi.org/10.22038/ijp.2016.6672

This study investigated the impact of open spaces in student achievement. The paper presents a cross-sectional study, with a random sample of 210 elementary students (3rd, 5th and 6th grades). The researchers collected data through interviews with experts, observation checklists, the Hermance's achievement motivation questionnaire and a researcher-constructed questionnaire to develop the study between 205-2016. They found that schools' open space had a significant impact on learning and academic achievement of elementary school students (P<0.05), based on self-reported perceptions and the Hermance's achievement motivation questionnaire. [288]

Publication type: Journal article
Study type: Field study
Sample: 210 students
Duration: Cross-sectional, single point in time
Age or developmental stage: 3rd, 5th and 6th grades

Gustafsson, P. E., Szczepanski, A., Nelson, N. & Gustafsson, P. A. Effects of an outdoor education intervention on the mental health of schoolchildren. *J. Adventure Educ. Outdoor Learn.* 12, 63–79 (2011).

This study presents the effects of an intervention of outdoor education on the mental health of school children. The authors used two elementary schools, one for control and one for intervention, with a total of 230 students. The intervention lasted one year and had two waves of data collection for comparison. The control school was an urban school, while the intervention school was in the outskirts of the city. Researchers collected data through a strengths and difficulties questionnaire that was answered by the parents. The study found no significant differences in the two schools, though there was a small improvement in the mental health of children in the intervention school. In addition, they found a difference regarding sex, as boys did better in the intervention school than girls. [289]

Publication type: Journal article
Study type: Quasi experimental study
Sample: 230 students
Duration: One year
Age or developmental stage: Elementary school

Indira Dutt. (2012). School Design and Students' Relationships with the Natural World. *Children, Youth and Environments,* 22(1), 198. https://doi.org/10.7721/chilyouenvi.22.1.0198

This paper studied the effects of the natural world - as mediated by indoor/outdoor elements at school - on student development and learning. Using the Bowen Island Community School near Vancouver BC as the school of study, a series of qualitative research methods were conducted: two focus groups, semi-structured interviews, photographs, and observation notes from the field. The study found that successful indoor/outdoor interfaces, as

well as plenty of play space in gardens and forests, provided students with great sense of joy, freedom, social cohesiveness, and aesthetic pleasure in relation to the built school environment [290].

Publication type: Journal article
Study type: Field study
Sample: 42 students (focus groups), 5 students (interviews)
Duration: 45-minute focus groups. Single point in time. Multiple methods.
Age or developmental stage: Grade 6th and 7th

Khan, M., McGeown, S. P., & Islam, M. Z. (2019). 'There is no better way to study science than to collect and analyse data in your own yard': outdoor classrooms and primary school children in Bangladesh. *Children's Geographies*, *17*(2), 217–230. https://doi.org/10.1080/14733285.2018.1490007

In this study they compared the academic achievement of the same third grade students in a rural school in Bangladesh in an indoor and an outdoor classroom. A set of 30 third graders took science classes in an and an outdoor classroom (amphitheater). The outdoor classroom design included considerations of seating, blackboard, and storage furniture specific to the class. After two weeks of instruction indoors they completed and achievement and test questionnaire afterwards. The same procedure followed in the outdoor classroom. In addition to this data, the researchers developed focus groups with teachers and students. The study found that children scores and engagement were higher when they were taught outdoors in comparison to the indoors. The focus groups highlighted the comfortable seating, ease of movement and better visibility of the outdoor classroom. The most significant gains in student attainment happened with the students that had the lowest grades in the first test. The study concluded that physical environmental quality of the space and greater enjoyment and participation likely improved attainment. [291]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 30 students
Duration: Two weeks inside and two weeks outside
Age or developmental stage: 3rd grade

Kuo, M., Barnes, M., & Jordan, C. (2019). Do Experiences With Nature Promote Learning? Converging Evidence of a Cause-and-Effect Relationship. *Frontiers in Psychology*, 10, 305. https://doi.org/10.3389/fpsyg.2019.00305

Kuo, Barnes, and Jordan address how experiences with the outdoors affect learning in students. The literature review involves studies, reports, and other articles on nature and its effects on learning from the point of view of observers and participants. Fifty studies were focused on nature's effect on behavior in the environment. Standardized tests, graduation rates, self-discipline, physical activity and fitness, and levels of stress were measured in the review. The review found that in group settings, nature allowed for less fidgeting, which allowed for less distraction, and a better learning environment. Learning for students with disadvantages benefitted greatly from nature-based learning. Nature-based learning increased interest in uninterested students. It also improved grades, reduced dropout rates, disruptive episodes, and helped to

close income-related gaps. Low-performing students were found to improve and become more leaders in nature-based environments. The benefits of school gardens, green schoolyards, and green walls need to be analyzed more. Teachers are encouraged to hold more nature-based classrooms. [292]

Publication type: Journal article
Study type: Literature Review
Sample: 50
Duration: Cross-sectional
Age or developmental stage: Preschool to Secondary

Kuo, M., Browning, M. H. E. M. & Penner, M. L. Do lessons in nature boost subsequent classroom engagement? Refueling students in flight. *Front. Psychol.* 8, 1–15 (2018).

This paper presents a quasi-experimental study where researchers paired lessons in a natural setting with lessons in an indoor classroom to compare student engagement. The study paired lessons with the same teacher, students in the class, teaching style, week of the semester and time of the day. In this way, they controlled for multiple variables that may cause differences in their results. They developed 100 paired comparisons over 10 different topics in 10 weeks of the school year in 2 third grade classrooms. They found that classroom engagement was significantly better after the outdoor lessons for 4 of the 5 measures they collected: teacher ratings, teacher redirects (teachers stopping instruction to get back on task), photo-based ratings and a composite index. The only measure that didn't show a significant increase was student ratings. The researchers conclude that lessons in nature may help students engage better in the following lesson and argue for including more of this kind of lessons in formal education. [293]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 2 classrooms, 100 paired lessons and comparisons
Duration: Longitudinal, 10 weeks
Age or developmental stage: Third grade

Lau, S. S. Y., Gou, Z., & Liu, Y. (2014). Healthy campus by open space design: Approaches and guidelines. *Frontiers of Architectural Research,* 3(4), 452–467. https://doi.org/10.1016/j.foar.2014.06.006

In this paper, the authors reviewed literature on outdoor green spaces on college campuses to determine the attributes of these spaces that benefited student health and well-being. They also conducted a case study of two campuses - one in a dense urban environment and one more rural, to compare and test their spatial attributes in practice. The authors identified three primary spatial attributes of these outdoor public spaces with the greatest benefit: healing gardens where greenery and plants produce restorative effects; flexible spaces that accommodate functional needs of different activities; and green buildings that incorporate open space as a catalyst for integrated eco-system. In the case studies, authors found that overcrowded or too-dense urban environments would decrease the square footage allotted for these green spaces; on the flip side, having smaller

spaces can enable a more intimate connection with nature, versus a too-spread-out green space [294].

Publication type: Journal article
Study type: Literature review and case study
Sample: 2 case studies

Malone, K., & Tranter, P. (2017). Schoolgrounds " Children ' s Environmental Learning and the Use , Design and Management of Schoolgrounds 1 environmental learning. It is based on a three-year project that schools . Data collection occurred through multiple methods , children and teacher. *Children, Youth and Environments,* 13(2), 87–137.

The authors focused their research on outdoor areas of schools (the "schoolgrounds") and the effect that the design of these spaces can have on learning. Next, the researchers conducted their own qualitative research, which involved studying students at five primary schools in Australia. The research consisted of behavior observation, general observations and informal discussions, more formal interviews with students, and having students sketch their ideal environments. The researchers found that for many of the schools, the outdoor areas were treated as a reward/punishment. This contrasted with other schools where the outdoors were used for lessons, which fostered a greater connection to the environment. As in other studies, cases where students had a role in the design of the schoolgrounds enabled students to take more ownership over those spaces. Many of the schools poured lots of resources into "pristine" places but the students benefited more from more impromptu spaces, tall grass to play in, lots of toys and games available, and the ability to wander around in nature without feeling the need to stay on any prescribed pathways [295]

Publication type: Journal article
Study type: Field study
Sample: 5 schools

Maynard, T., & Waters, J. (2007). Learning in the outdoor environment: a missed opportunity? *Early Years*, 27, 255 - 265.

Maynard and Waters address how teachers at school used the outdoor environment for learning after the Welsh Assembly Government for children ages three to seven years old announced the proposed Foundation Phase of indoor and outdoor learning. The paper used four schools in South Wales to analyze the indoor and outdoor learning and personal and social development of children ages three to seven years. The teachers were observed by researchers, and also interviewed to understand what they had seen and experienced. The research project found that teachers did not fully use the framework given to them and caused students to miss out on the opportunities in outdoor environments. The size, condition, and location of outdoor places were not always sustainable for learning and play. Students were not always able to see those spaces, which could have caused a disconnect. Teachers were also used to teach differently and were not taught specifically how learning could be beneficial at first. [296]

Publication type: Journal article
Study type: Research Project and Paper
Sample: 4
Duration: Longitudinal, During implementation of phases
Age or developmental stage: Three to Seven Years Old

Meredith, G. R. et al. Minimum Time Dose in Nature to Positively Impact the Mental Health of College-Aged Students, and How to Measure It: A Scoping Review. *Front. Psychol.* 10, 1–16 (2020).

This paper presents a literature review focusing on the effects of nature on the mental health and well being of college age students. The review used the PRISMA methodology and after a selection process included only a set of 14 papers. Most papers came from Japan, and a smaller selection came from the US and Sweden. The main takeaway from the review is that as little as 10 minutes of sitting or walking in natural settings (including parks, woods and forests) can significantly and positively impact psychological and physiological markers of mental health in college age students. Most studies looking at about 15 minutes in nature showed significant positive physiological effects. [297]

Publication type: Journal article
Study type: Literature review
Sample: 14 papers

Nel, A., Joubert, I., & Hartell, C. (2017). Teachers' perceptions on the design and use of an outdoor learning environment for sensory and motor stimulation. *South African Journal of Childhood Education,* 7(1), 11. https://doi.org/10.4102/sajce.v7i1.482

This study explores the effects & importance of outdoor classrooms/play areas/learning spaces for young children (pre-k), in their development of sensory, cognitive, and motor skills; they further discuss the impact that development in these areas have on in-classroom learning in their older, school-age years. The researchers used three child daycare schools in South Africa for their study. The researchers used a mix of qualitative research methods, including archival research, photos and videos, and interviews with daycare teachers to gather data and summarize their findings. While contradictory perspectives emerged on the specific impact of outdoor learning environments, the consensus is that outdoor learning spaces are valuable, especially for young children. The research gave the authors a "checklist" of the "ideal" outdoor learning space, including play areas and connection to nature. Outdoor learning areas can aid young children in development of sensory and motor skills, cognitive development, and general health/muscle development, all of which can impact a child's learning ability once they are school-age and learning in an indoor classroom setting [298.]

Publication type: Journal article
Study type: Research Study
Sample: three nurseries, 3 teachers
Duration: Cross-sectional, Longitudinal, Single point in time
Age or developmental stage: Preschool

Norwood, M. F., Lakhani, A., & Kendall, E. (2021). Teaching traditional indoor school lessons in nature: The effects on student learning and behaviour. *Landscape and Urban Planning,* 206(April 2020), 103963. https://doi.org/10.1016/j.landurbplan.2020.103963

In this study they developed a quasi-experimental study over an academic term of 10 weeks in a socioeconomically disadvantaged community. They used three different classes for the experiment. Two of those three classes were taught indoors for 5 weeks and relocated to outdoor classrooms for the remaining 5 weeks. One class was taught fully indoors as a control. They used measures such as teacher ratings, researcher observations and grades of the students. They found that students were more on-task in outdoor classrooms, and that this effect lasted several weeks, indicating more engagement in class activities. Nonetheless, they found that there were no differences in student grades.[299]

Publication type: Journal article
Study type: Research Study
Sample: three classes
Duration: one term (10 weeks)
Age or developmental stage: 13 to 14 years

Romney, B.M. (1972). *The Effects of Windowless Classrooms on the Cognitive and Affective Behavior of Elementary School Students*.

Romney addresses how windowless classrooms affect learning. Specifically, concept formation, perceptual ability, and rote learning. The thesis involved two sixth-grade classes that were identical. Class A1 involved all existing windows with coverings on them, and Class A2 was left unmodified. Students were randomly divided into three groups to be tested and studied. Students had to memorize seven nonsense trigrams, concept formation tests, and the MacGregor Perceptual Index Observations were taken on behavior like destructive behavior, aggressive, and boredom. The thesis found that in the study Class A1 performed better with windows compared to class A2 in a windowless environment on the rote learning task. Class A1 was also found to perform better compared to Class A2 on the conceptual learning task in a windowless environment. In the perceptual tasks, the case study found that there were no differences. Aggression was found to increase in both classes in windowless environments. Teachers were found to increase in frustration in windowless classrooms. [300]

Publication type: Paper
Study type: Thesis
Sample: 2 sixth grade classes
Duration: Single Point in Time
Age or developmental stage: Sixth Grade

Samuel F. Dennis, Jr., Alexandra Wells, & Candace Bishop. (2014). A Post-Occupancy Study of Nature-Based Outdoor Classrooms in Early Childhood Education. *Children, Youth and Environments,* 24(2), 35. https://doi.org/10.7721/chilyoutenvi.24.2.0035

To evaluate the performance of several outdoor classrooms at the early childhood education level, specifically as designed and implemented by

two organizations specializing in outdoor classrooms: Nature Explore and Outdoor Classroom Project. As a result of this POE, outdoor classroom designers can take best practices to improve outdoor classrooms in the future. The authors identified 21 outdoor classrooms across different climate zones in the US and reached out to conduct interviews. Out of the 21, 11 participated in the research; interviews were conducted with teachers, administrators, and other adults associated with each of 11 outdoor classrooms across the US. The POE supported the existing research into the benefits of outdoor classrooms. Specifically, 5 themes were highlighted by the authors as being the most beneficial/impactful - outdoor classrooms: 1) maximized choices, 2) provided many distinct spaces, especially child-sized ones, 3) embedded play affordances within pathways and borders, 4) encouraged spatial evolution, and 5) supported ongoing stakeholder engagement [301].

Publication type: Journal article
Study type: Research Study
Sample: 11 study sites
Duration: Single point in time

Sivarajah, S., Smith, S. M., & Thomas, S. C. (2018). Tree cover and species composition effects on academic performance of primary school students. *PLoS ONE*, 13(2), 1–11. https://doi.org/10.1371/journal.pone.0193254

Sivarajah, Smith, and Thomas address how the academic performance of primary students is affected by species composition and tree cover at their schools. The methods involved in the study were 387 schools from the Toronto District School Board and performance scores from 3rd and 6th graders. The study measured the relationships between tree cover, tree diversity, and tree species on school property and their effect on students. The study used the learning opportunity index (LOI), which is a composite, regionally, index of challenges that are external to learning. The study also focused on standardized performance tests scores of the students involved in the study. There were 532 students involved in the study. The research study found that the learning opportunity index had the biggest impact on the academic performance of students. Greenspace, like grass, and the proportion of tree cover were also found to have a significant impact on student performance. Tree cover and green space could also be a positive predictors for performance. [302]

Publication type: Journal Article
Study type: Research Study
Sample: 532 students, 387 schools
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Primary, 3rd and 6th Grade

Taylor, A. F., Kuo, F. E., & Sullivan, W. C. (2001). Coping with add: The Surprising Connection to Green Play Settings. *Environment and Behavior*, 33(1), 54–77. https://doi.org/10.1177/00139160121972864

Taylor, Kuo, and Sullivan address how children with Attention Deficit Disorder are affected by the exposure to nature between subjects. Interviews were

given to children with ADD and their parents and professionals on ADD. Classroom observation of four children with ADD was also analyzed and measurements were taken. The children were ten to eleven years old. A questionnaire was given to four different families about activities children engaged in, understanding ADD, appropriation of rating scales, and if the natures measures were usable and interpretable. Data and measurements were collected from mid-September to October. The study found that children's ability to function was better than normal after activities in green settings. It also found that when a children's play area was more and more green there was a decrease in the severity of the children's deficit symptoms. This shows that contact with nature may support attentional functioning for children who need additional support. [303]

Publication type: Journal Article
Study type: Case Study
Sample: 4
Duration: Longitudinal, .5 Months
Age or developmental stage: 10 to 11 Years Old

Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. *Journal of Environmental Psychology*, 15(1), 77–85. https://doi.org/10.1016/0272-4944(95)90016-0

Tennessen and Cimprich address the theory that increased demands for attention affect individuals' capacity to direct attention may become fatigued. The study involved university dormitory residents of 72 undergraduate students and how their views out of their dorms affected the test of directed attention. There were four groups of views from natural to all built. The windows were all of similar sizes and students were assigned rooms based upon seniority. 115 students were first asked, but only 72 participated. Measurements were taken with the subject and researcher in the room. The Necker Cover Pattern Control tests, which made the ability to inhibit competing stimuli were used, and the Digit Span Test, along with the Symbol Digit Modalities Test. The study found that the students that had natural views were able to direct attention better than those with fewer natural views from their windows. Those with less natural or built views scored significantly lower than those with natural views on the Symbol Digit Modalities Test. [304]

Publication type: Journal Article
Study type: Case Study
Sample: 72
Duration: Longitudinal
Age or developmental stage: 8 to 9 Years Old

Wells, N. M. (2000). At Home with Nature: Effects of "Greenness" on Children's Cognitive Functioning. *Environment and Behavior*, 32(6), 775–795. https://doi.org/10.1177/00139160021972793

Wells addresses how a close natural environment affects the well-being of children in poor urban areas. Specifically, the cognitive function of children before and after relocation. The study involved 17 children, seven to twelve years old, from low-income families in a self-help housing program that

allowed them to construct and purchase a new house. The naturalness of the homes was analyzed from the window view of nature in the living room, bedrooms, and kitchen, and the material of the yard was also measured. Mothers were given a series of questions about their children's abilities to focus their attention and their cognitive functioning. Measurements were taken during the early summer and the following summer after they had been interviewed house for several months. The study found that children with new homes that improved in greenness with the environment of nature and plants had the highest levels of cognitive functioning after the move. Children with the most improvement in natural environments had the greatest ability to change and direct their attention. [305]

Publication type: Journal Article
Study type: Research Article/Case Study
Sample: 17
Duration: Longitudinal, Several Months
Age or developmental stage: 7 to 12 Years Old

Wells, N. M., & Evans, G. W. (2003). Environment and Behavior NEARBY NATURE A Buffer of Life Stress Among Rural Children. *Environment*, 35(3), 311–330. https://doi.org/10.1177/0013916503251445

Wells and Evans address how nature affects the life stress levels of children who live in rural areas near their homes. The methods involved in this research study were 337 children who were on, on average, 9.2 years old, in grades 3rd through 5th and their psychological bell-being was analyzed and compared due to the vegetational levels outside/near their residential environment. The study measured how the residential environment and its levels of vegetation to analyze how they affected the life stress of children. The study focused on the psychological well-being of children and measured the impact of stressful events. The research study found that if there were nature and vegetation near a child's residential environment, it would help to moderate the life stress of children. The study also found that life stress lowered as the levels of nature near a home increased compared to the life stress levels of children with less nature near their home. [306]

Publication type: Journal Article
Study type: Research Study
Sample: 337 Students
Duration: Cross-sectional, Longitudinal
Age or developmental stage: 3rd through 5th Grade

Weyland, B. (2021). Movement and outdoor spaces as quality indicators in the design of school buildings. *Journal of Physical Education and Sport*, 21(1), 624–631. https://doi.org/10.7752/jpes.2021.s1073

The author's goal is to make the case that, in the design competition for schools and other learning environments, it is crucial to involve at least one expert in teaching pedagogy. The author uses as a case study the competition for a school in Milan, Italy. The jury for the competition included an expert in teaching/educational pedagogy. The author details the competition and

the process of evaluation for the jury, making special note of the criteria that was used by the jury, which included an intentional overlap of architectural features (relation to context, connection to nature) and pedagogical features (flexibility of space, enabling of easy movement between spaces by students and teachers). The winning design was characterized as having the following attributes: 1) excellent connection with the neighborhood/context, 2) forms recalled a desirable organic nature, 3) thoughtful use of landscape enables connection to nature, 4) interconnection of volumes with covered walkways enables some activities to be moved outside, 5) permeability of interiors and central courtyard enable flexibility and easy communication/coming together, 6) school also functions as a civic center for the community [307].

Publication type: Journal article
Study type: Case study

School and classroom size

Darling-Hammond, L., Ross, P., & Milliken, M. (2006). High School Size, Organization, and Content: What Matters for Student Success? *Brookings Papers on Education Policy*, 2006(1), 163–203. https://doi.org/10.1353/pep.2007.0001

In this paper, the authors' focus in reviewing the literature is to identify design, pedagogical, and philosophical attributes that contribute to student success in high schools. Of particular focus are school size/density, curriculum, school mission, and adaptable pedagogy. The researchers reviewed the relevant literature and subdivided their main findings into these categories: 1) School size, 2) School Design, and 3) the School Change Process. Size of school (# of students) as well as density (# students per classroom/teacher) were found to be important variables. The authors note that size matters "because it can create condition conducive to other relationships and opportunities more directly relevant to student attachment and learning". They found that the conditions/design features that affect student success are 1) mechanisms that personalize student-teacher relationships, 2) a shared school mission emphasizing academic success creates cohesiveness, 3) a strong core curriculum that challenges students, 4) instruction that is adaptable and responsive to student learning, and 5) a professional community that encourages teachers to take responsibility for student learning. [308]

Publication type: Journal article
Study type: Literature review

Hand, K. (2014). The Relationship Between the Physical Classroom Environment and the Academic Functioning of School Age Males and Females A doctoral project submitted to the faculty of the Shirley Mount Hufstedler School of Ed. February.

The author conducted a thorough literature review with the purpose of

understanding more about the effects of classroom design on student performance and well-being, with particular focus on elementary school students. The environmental factors of most significance are density/ crowding in the classroom, and flexibility of furniture. The author conducts a review of the relevant literature to summarize her primary findings on the topics at hand. The two primary takeaways from the author's review are that students perform better in classrooms with an ideal level of density, i.e. not overcrowded, as they feel more ownership and connection with the teacher and other students. Also, easily movable, and reconfigurable furniture combinations are important so that classrooms can flex between a lecture format and small group work formats [309].

Publication type: Doctoral Dissertation
Study type: Literature review

Merike Darmody, & Emer Smyth. (2012). Exploring School and Classroom Environments in Irish Primary Schools. ***Children, Youth and Environments***, 22(1), 178. https://doi.org/10.7721/chilyoutenvi.22.1.0178

Darmody and Smyth performed qualitative research on primary schools in Ireland by conducting interviews and focus groups with teachers and students. The authors selected six schools that represented a range of total school population, average classroom size, age of building, and urban vs rural settings. The purpose was to obtain firsthand perspectives from building users in order to supplement existing quantitative research on student performance. Researchers found that, in general, smaller school and classroom sizes (# of students) were preferable, but that larger classroom dimensions (i.e. less student density) were better. The research also backed up existing research as to preferred environmental qualities, i.e. more daylight, more control over temperature and air quality, less ambient noise, etc [310].

Publication type: Journal article
Study type: Case study
Sample: 50 students
Duration: Single point in time
Age or developmental stage: 9 to 10 and 11 to 12 (focus groups)

Moore, G. T., & Lackney, J. A. (1993). School Design : Crisis , Educational Performance and Design Applications Author (s): Gary T . Moore and Jeffrey A . Lackney Source : ***Children's Environments*** , Vol . 10 , No . 2 , School Design : A Continuous Process Published by : Board of Regents of . 10(2), 99–112.

Using existing research into spatial attributes of schools and student performance, the authors aim to distill the most impactful attributes of school design on student performance. They review the literature on spatial attributes of schools, notably school size (area and population), classroom size and density, location and noise, and availability of secluded study areas. As a result of their literature review, the authors conclude that the ideal school is smaller than the current average; they suggest capping schools at 500-600 students, as a smaller community gives students a greater sense of ownership. They follow this up by suggesting that successful schools have what they refer to as "well-defined activity pockets", or in other words, a

variety of spaces that offer social/private opportunities, loud/quiet spaces, etc. The idea of flexibility of space goes along with this attribute [311].

Publication type: Journal article
Study type: Literature review, Theory development

Interior Design (Color, Openness, Spatial)

Alterator, S., & Deed, C. (2013). Teacher adaptation to open learning spaces. *Issues in Educational Research, 23(3), 315–330.*

In this paper, the authors use a case study from a school in Victoria, Australia to determine teacher perceptions in an open plan environment and their effect on student performance. The researchers identified four teachers with varying levels of experience at a junior secondary school in Australia and conducted in-depth interviews to gauge their perceptions of the open plan as it related to their teaching, as compared to more traditional classroom environments. The researchers identified key areas of focus based on interviews with teachers: flexibility of space (more possibilities); increased visibility and scrutiny (teachers could be seen and observed at all times, meaning less privacy, but also elevated performance.); De-emphasis on hierarchy; collective practice; team orientation; and interactions and authority (with open classrooms, anyone can meander in and through - the classroom unit is dissolved and the neighborhood or school becomes more of a community) [317]

Publication type: Journal article
Study type: Case study
Sample: 4 teachers
Duration: Single point in time
Age or developmental stage: Teachers

Ba~o~lu, Z. (2002). A comparative study on color preferences of children for their school environments : Two private schools in Ankara. http://repository.bilkent.edu.tr/handle/11693/15308

Ba~o~lu addresses how preferences of color for classrooms based on student preference, age, and gender were analyzed. The study involved two private schools in Urban Ankara. The study focused on the preference of colors of the school environment from a children's perspective and how their beliefs affect learning. The study used literature search, observational research, and survey to measure the preferences. 275 students were involved from second, fourth, and seventh graders. The study found that there was no association between gender and hue preference. The study also found there was no association between age and hue preference. The ranking of color preference was blue, green, red, yellow, purple, monochromatic colors, and orange. The study found that there was a preference toward cool colors compared to

warm colors. The preference for warm colors decreased as age increased and the preference for cool colors increased as age increased. The preferred color schemes were one with blue also with green and purple. [325]

Publication type: Paper
Study type: Thesis
Sample: 275
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Elementary

Brooker, A., & Franklin, A. (2016). The effect of colour on children's cognitive performance. *British Journal of Educational Psychology*, 86(2), 241–255. https://doi.org/10.1111/bjep.12101

Brooker and Franklin address how and if children are affected in their cognitive performance dependent on the color in their learning environment. The study involved 359 students from 11 schools in the UK with an average age of 8.74 years. The students were given tasks that measured cognitive abilities while a screen showed one of eight colors and then a grey screen and the results were analyzed and compared. The methods involved measuring performance, with the grey screen acting as the baseline and the colors being red, green, yellow, purple, orange, blue, with light red and light blue also being added, along with light grey. The study found that there was a significant difference in student performance depending on the color being shown to the student on the screen. The study found that there was a performance that was worse when the color red was shown on screen compared to the color grey. [326]

Publication type: Journal Article
Study type: Research Study
Sample: 359 Students
Duration: Cross-sectional, Longitudinal
Age or developmental stage: 8 to 9 Years Old

Chang, Bo., Xu, R., and Watt, T. (2018). The Impact of Colors on Learning, Adult Education Research Conference. https://newprairiepress.org/aerc/2018/papers/30

Chang, Xu, and Watt address how learners' learning is impacted by colors, specifically, how it affects their emotions and cognition. The review involved papers, case studies, other reviews, research, and journal articles that were about the implications, color, emotions, cognition, and how color and memory interact. The focus was on supporting learners and influence learners' by changing their motivation and attitude. The review found that cognitive information needs to be pictorial and verbal for the best processing for learning. The review also found that colors help learners by allowing them to be able to increase their attention levels once certain information. Warm colors are found to increase attention. Color can also help to improve the efficiency of learners. The review found that changing the hue can affect the recall of learners. Blue backgrounds were found to increase the likelihood of recall of information. The review also found that color affects behavior and affects performance, intentions, and cognitive abilities. [323]

Publication type: Conference paper
Study type: Review Paper
Sample: NA
Duration: Cross-sectional
Age or developmental stage: School Age

Costa, M., Frumento, S., Nese, M., & Predieri, I. (2018). Interior Color and Psychological Functioning in a University Residence Hall. *Frontiers in psychology*, 9, 1580. https://doi.org/10.3389/fpsyg.2018.01580

Costa, Frumento, Nese, and Predieri address how students were affected by the interior color in their residence hall and its effect on their mood and studying. The study involved 443 students that lived in six buildings for around 13.33 months. The study measured hue, lightness, lightness preference, color preference, the effects on studying, and the effects on mood. The study had 230 males and 213 females. Blue, yellow, red, green, and violet walls were painted in the six different buildings. A questionnaire was given on color preference and the socio-demographic date was measured on each student. The study found that the largest preference was for a blue interior. The order was blue, then green, then violet, orange, yellow, and last red. The study also found that there were differences in preference based on gender for violet and blue. There was also a preference bias based on what color interior that students lived in. The study found that the preferred ceiling color was white. There was also a room-lightness found to be significantly affected by the color of the rooms' interior. The color blue was found to be believed to create the best studying environment. There was also a relationship, that was significant, between the preference for blue and a calm mood. [320]

Publication type: Journal Article
Study type: Case Study
Sample: 443
Duration: Cross-sectional, Longitudinal, 13.33 months
Age or developmental stage: University

Deed, C., & Lesko, T. (2015). 'Unwalling' the classroom: teacher reaction and adaptation. *Learning Environments Research,* 18(2), 217–231. https://doi.org/10.1007/s10984-015-9181-6

The researchers use a case study and interviews to explore teacher perceptions when transitioning from a traditional classroom environment to an open, flexible shared space, and how this affects pedogogy and practice. The researchers identified teachers at four newly built Year 7-10 schools in Victoria, Australia. They conducted in-depth interviews with many of the teachers to explore their reactions to the abrupt transition. Many of the teachers expressed frustration and difficulty with the transition. From the interviews, it seems many went to the new buildings expecting to utilize a similar educational practice/pedagogy but were flummoxed when working in a large open room with ~100 students and a few other teachers, instead of the typical ~25 students and one teacher in a classroom. Nonetheless, the teachers expressed an openness to the new system, and noted that a

continual conversation and negotiation of pedagogy and cultural values with the other members at the school would lead to success [319]

Publication type: Journal article
Study type: Research study
Sample: 10 staff members
Duration: Single point in time
Age or developmental stage: Year 7-10 schools

Duyan, F., Ünver, R. (2016). A research on the effect of classroom wall colours on student's attention, *A|Z ITU Journal of Faculty of Architecture*. 13(2), 73-78. 10.5505/itujfa.2016.57441

Duyan and Ünver address how students' attention is affected by the wall color of their classroom walls. The study involved students ages 8 to 9 years old in primary schools. One primary school was private and the other primary school was a state school. 78 students were a part of the study. Five different colors were used and classroom walls were appointed those five different colors. Attention tests were given to the students, and performance was measured and analyzed. The study found that students who had the best performance on attention tests in the classroom painted purple. The order of best to worst performance based on wall color was purple, blue, green, yellow, and red. The study also found that students had the lowest performance on attention tests in the classroom painted red. The study also found that the scores for the private school students were more attentive than the scores for the state school students. [324]

Publication type: Journal Article
Study type: Case Study
Sample: 78
Duration: Cross-sectional, Longitudinal
Age or developmental stage: 8 to 9 Years Old

Gaines, K., & Curry, Z. (2011). *The Inclusive Classroom: The Effects of Color on Learning and Behavior.*

Gaines and Curry address how color in classrooms affects students of all abilities. It focused on disabilities and how inclusion needs to be in education and educational settings. The review focused on color theory, physiological and psychological aspects of color, and the inclusive classroom for students with disabilities. The review found that color is very important in functional learning spaces and for creating the best functional learning space, color needs to be included. The review also found that color impacts attention, achievement, and behavior. The recommendations are that the wall that students focus on when looking up after completing or doing work should be a medium hue in the same color range as the warm neutral color scheme of tan or sand that should be applied to the back of the classroom, and primary colors should be avoided, color preferences of children and students are important, the application of color can be used by students, and using different color tape may benefit students of all abilities.[322]

Publication type: Paper
Study type: Literature Review
Sample: 10 +/-
Duration: Cross-sectional
Age or developmental stage: School Children

Gilavand, A., & Hosseinpour, M. (2016). Investigating the impact of educational spaces painted on learning and educational achievement of elementary students in Ahvaz, Southwest of Iran. *International Journal of Pediatrics*, 4(2), 1387–1396. https://doi.org/10.22038/ijp.2016.6439

This study investigates the impact of color in learning environments on elementary student performance. The study used a random sample of 210 elementary students, as well as the Hermance's achievement motivation questionnaire, a researcher-constructed questionnaire (observation checklist), and student interviews. The study found that color in the educational setting had a significant moderate influence on student achievement, based on student's self-reported perceptions. [313]

Publication type: Journal article
Study type: Field study
Sample: 210 students
Duration: Cross-sectional, Single point in time
Age or developmental stage: 3rd, 5th and 6th grade

Llinares, C., Luis Higuera-Trujillo, J., Serra, J. (2021). Cold and warm coloured classrooms. Effects on students' attention and memory measured through psychological and neurophysiological responses. *Building and Environment*, 196. https://doi.org/10.1016/j.buildenv.2021.107726.

Llinares, Luis Higuera-Trujillo, and Serra address the effects that warm and cold hue-colored classroom walls had on memory and attention. The study involved 160 university students and measured their cognitive attention and memory functions. There were 12 warm and 12 cold hue color settings. The study was conducted in a virtual classroom. There were psychological and neuropsychological tests and metrics to analyze the students. The study measured the change in memory, attention, heart rate, and an electroencephalogram. The study found that on attention and memory tasks, cold hue colors increased arousal and improved performance. The study found that the colors that allowed for the best performance were yellowish-green and purple hues. The higher activation rate is significant because it showed a contradiction to other studies. The psychological memory task showed how performance increased when there were cold-hued colored classroom walls. The study concludes that these results showed be taken into consideration for guidelines of classrooms. [321]

Publication type: Journal Article
Study type: Case Study
Sample: 160
Duration: Cross-sectional, Single Point in Time
Age or developmental stage: University

Lorraine E. Maxwell, & Raechel French. (2016). Elementary School Library Design: Student Perceptions of a Learning Commons. *Children, Youth and Environments,* 26(2), 61. https://doi.org/10.7721/chilyoutenvi.26.2.0061

This paper analyzes the usage of libraries in old elementary schools versus more open "learning commons" in the new schools, as well as student perceptions of these spaces. The researchers conducted a study of two schools in a New England school district. Both schools, situated in old buildings (with traditional libraries), made plans to move into new buildings (with more modern learning commons). The researchers conducted a questionnaire of 3rd, 4th, and 5th graders in the last year at the old school, and then again at the first year in the new school, to gauge their perceptions between these two spaces. Researchers also observed usage between the two spaces. Overall, there was much greater preference for the learning commons - which involved an enclosed space for books, required by code, but much more open distribution of other spaces, such as group study areas, social areas, areas for eating, quiet study space, computer spaces, etc. [315.]

Publication type: Journal article
Study type: Research Study
Sample: 410 questionnaires (year 1), 457 questionnaires (year 2)
Duration: 2 years, pre-post
Age or developmental stage: 3rd, 4th and 5th grade

Kirkeby, I. M., Jensen, B. B., Larsen, K., & Kural, R. (2015). Designing for health in school buildings: Between research and practice. *Scandinavian Journal of Public Health*, 43(3), 260–268. https://doi.org/10.1177/1403494815569378

This article researches the kind of knowledge architectural practitioners use when designing schools, and the link (or, the divide) between architects and educators when it comes to research and practice. The authors developed a series of qualitative interviews with architects, teachers, and other school officials pertaining to the knowledge and information that goes into the design of schools, through the lens of student health. Practitioners mostly made use of concepts, examples/pictures of precedents, or thought-provoking knowledge in their designs. They found issues in three areas: 1) there is a discrepancy between knowledge used in practice and knowledge traditionally produced by research, 2) the link tying research-knowledge and practice-knowledge is weak, and 3) practitioners' knowledge was often inspired by personal experience, making it vulnerable/not necessarily universal [316.]

Publication type: Journal article
Study type: Research Study
Sample: 12 semi-structured interviews
Duration: point in time

Küller, R., Mikellides, B., & Janssens, J. (2009). Color, arousal, and performance - A comparison of three experiments. *Color Research and Application*, 34(2), 141–152. https://doi.org/10.1002/col.20476

Küller, Mikellides, and Janssens address how three studies that analyzed color affected the arousal levels and performance of high school and university

students. The methods involved in the study involved collecting information from the three studies and comparing and analyzing them together. The first study compared gray and colorful rooms, while the second and third studies compared red and blue rooms. The heart rate and mood of participants were also measured and compared. The participants in study 1 were 12 high school and university students. The participants in study 2 were 25 students from an architecture school. The participants in study 3 were 20 students from a university. The study found that emotions were affected by the color of the rooms and the color red caused the brain to enter a more excited state and sometimes even slowed the heart rate. The study also found that if someone enters a room in a negative mood, the color could increase this negative mood and affect performance. [327]

Publication type: Journal Article
Study type: Experimental Study, Literature Review
Sample: 57 Students, 3 Studies
Duration: Cross-sectional, Longitudinal
Age or developmental stage: High School and University

McCoy, J. M., & Evans, G. W. (2002). The potential role of the physical environment in fostering creativity. *Creativity Research Journal*, 14(3–4), 409–426. https://doi.org/10.1207/S15326934CRJ1434~11

This paper presents two studies investigating the role of specific interior design elements on creativity with 20 pre-college students. To develop the study, first the authors identified 5 environmental characteristics that independently predicted greater perceived creativity: complexity of visual detail, views of nature, use of natural materials, fewer cool colors used, less use of manufactured or composite surface materials. The first study was developed using 60 pictures and sorting them using these characteristics. The second study developed tests of actual creative performance in two different settings: one with high rated creative potential (indoor/outdoor space), and one with low rated potential (hallway). To rate creativity, they used the Torrance Test of Creative Thinking (TTCT; Torrance, 1966), as well as the development of a collage that was rated after by 6 independent raters. The study found that creative performance was greater in the space that had been rated higher for creativity. [312]

Publication type: Journal article
Study type: Research Study
Sample: 20
Duration: Single point in time
Age or developmental stage: Pre-college students

Read, M. A., Sugawara, A. I., & Brandt, J. A. (1999). Impact of space and color in the physical environment on preschool children's cooperative behavior. *Environment and Behavior*, 31(3), 413–428. https://doi.org/10.1177/00139169921972173

Read, Sugawaram and Brandt address how preschool children are impacted by the color and space of their built environment. Specifically, how children's cooperative behavior is affected. The methods involved in this study were 30

children ages 3 to 5 years old and they were divided into eight groups based on their age while analyzed while completing different tasks. The children were measured with four different treatment conditions in a separate room. The rooms involved differing wall colors and ceiling heights. The room could be observed with a one-way window. The study first occurred behavioral measurements by a researcher for two weeks, then 5 weeks for the collection of data. The children were also videotaped so that could be then data coded. The study found that differences in wall color or ceiling height related to cooperative behavior that was at higher levels for preschool children. The study also found that developmental levels and gender could indicate predictions for the behavior of children. [328]

Publication type: Journal Article
Study type: Empirical Study
Sample: 30 Children
Duration: Cross-sectional, Longitudinal, 5 Weeks
Age or developmental stage: Preschool

Sigurdardóttir, A. K., & Hjartarson, T. (2011). School buildings for the 21st century: Some features of new school buildings in Iceland. *Center for Educational Policy Studies Journal,* 1(2), 25–43.

This study aimed at finding changes in the designs of new schools in Iceland, and their possible effects on teaching. The researchers set out to observe and analyze the differences between 16 schools built in the 20th century and 4 schools built in the 21st century in Iceland, in order to distill specific trends in school design and education. They first conducted non-intrusive, observational research by visiting each of the 20 schools to document various architectural qualities and characteristics, including photographs, and supplemented it with in-depth interviews with teachers from each of the schools. They found a clear evolution of schools/education in the 21st century. School design is centered around flexibility, flow, openness, and teamwork. Schools are characterized by clusters of classrooms and open spaces, transparent/movable boundaries, and other shared spaces, rather than traditional hallways and classrooms. They found that teachers were working in shared setting collaborate more, and students had more choice and variation in where and how they learn [318.]

Publication type: Journal article
Study type: Research study
Sample: 20 schools
Duration: Single point in time

Wu, X., Oldfield, P., & Heath, T. (2020). Spatial openness and student activities in an atrium: A parametric evaluation of a social informal learning environment. *Building and Environment,* 182(February), 107141. https://doi.org/10.1016/j.buildenv.2020.107141

Wu et al. seek to relate spatial openness to opportunities for social learning. The Telford Exhibition Hall at the University of Nottingham, UK, a three-story space, was the location of study. Researchers used parametric tools to quantitatively assess the visual area and visual volume of the Hall from

four spaces: 1-, 2, and 3-story height spaces, and the large open staircase. Researchers performed social research to assess human behavior; they took a series of panoramic photographs during one week of study, and analyzed the activities being performed by the subjects. Next, they selected 15 students to participate in informal interviews to lend more context to observations. "See and be seen" activities, like waiting or looking around, were more common in the spaces with more openness. Spaces with a range of spatial openness provided maximum flexibility for a number of activities, including group study, eating, etc. More research is necessary in other locales to support the findings of this study. [314]

Publication type: Journal article
Study type: Case study
Sample: number
Duration: Single point in time
Age or developmental stage: 15 years-old

Furniture, Technology, Flexible Spaces and Active Learning

Aagaard, J., & Storr-Paulsen, A. (1995). A comparative study of three different kinds of school furniture. *Ergonomics*, 38(5), 1025–1035. https://doi.org/10.1080/00140139508925169

Aagaard-Hansen and Storr-Paulsen address three different types of school furniture. The study used 144 children that were divided into nine classrooms that had three in the third form, three in the fifth form, and three in the second form. The age range was about 7 to 11 years old. Group A had newly made furniture, but it was original style. Group B had backup furniture which was based on the recommendations and was about 15 cm higher than the original and the angle of the desktop could be adjusted. Group C received the furniture that was constructed based on the measurements of Group A and B's furniture, but exactly in between them. The study found that of the two tilting types of tables, the highest one was significantly better than the two others because of global assessment, reading position, backrest, chair height, and table height. The tiltable table-top was seen as the most positive independent of the furniture height. [378]

Publication type: Journal Article
Study type: Comparative Study
Sample: 144 Students, 3 types of furniture
Duration: Cross-sectional, Longitudinal
Age or developmental stage: 7 to 11 Years Old

Ashley, J., Frostén, S., & Klemens, J. (2020). Challenging "If You Build It, They Will Come": Success of Active Learning Is About More Than the Space. *Planning for Higher Education,* 48(2), 25–35. https://acces.bibl.ulaval.ca/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=143131871&amp%0Alang=-fr&site=ehost-live

In this article the authors make the argument that simply building flexible/active learning environments, on its own, does not guarantee success, or that students will decide to attend a school or university simply for that reason. Their purpose is to argue for and suggest strategies school administrations can take to maximize the chances for success in active learning spaces, which involve the human component of administrators and educators. The authors performed a case study at their own university, Thomas Jefferson University, into active learning spaces. They also toured several other institutions to observe active learning environments elsewhere, to look at best practices. The authors argue that, simply having active learning spaces does not guarantee student engagement, performance, or even attendance. An intentional program of stakeholder engagement, teacher training, and ongoing support is necessary to supplement active classroom design. In their conclusions they state "We discovered that our strategies to mindfully plan and implement collaborative classrooms have been the essential element in the success of the initiative. Much more than any particular aspect of the design or technology of the individual spaces, the human factor of faculty willing to accept change, iterate, and evolve has been key." [349]

Publication type: Article
Study type: Logical argumentation, case study
Age or developmental stage: University

Attai, S.L., Reyes, J.C., Davis, J.L. et al. Investigating the impact of flexible furniture in the elementary classroom. *Learning Environ Res* 24, 153–167 (2021). https://doi.org/10.1007/s10984-020-09322-1

Attai, Carmona Reyes, Davis, York, Ranney, and Hyde address how furniture that is flexible can be used to facilitate the best environment for teaching and learning. The study involved ten classrooms that held third and fourth-grade students. There were 206, 3rd and 4th graders, involved in the study. The study involved measurement and observations of the classroom for eight weeks. Group A classrooms involved Professional Development and flexible furniture Group B classrooms involved traditional furniture. The study found that flexible furniture classrooms created the greatest level of satisfaction with the learning environment for students when compared to the traditional furniture classroom. The study also found that there were more opportunities for student autonomy with flexible furniture. The flexible furniture was found to allow for the best use of space to create a learning environment that can change based on the needs of the space. The flexible furniture can improve student choice, perceptions of the movement, active learning, and movement. [364]

Publication type: Journal article
Study type: Case study
Sample: 206 students
Duration: Longitudinal, 8 Weeks

Age or developmental stage: 3rd and 4th Graders

Beery, T. A., Shell, D., Gillespie, G., & Werdman, E. (2013). The impact of learning space on teaching behaviors. *Nurse Education in Practice,* 13(5), 382–387. https://doi.org/10.1016/j.nepr.2012.11.001

In this paper, the authors aimed to determine and then compare teaching behaviors in traditional versus collaborative/flexible classrooms. The research team worked with expert teachers at the University of Cincinnati College of Nursing to record and observe videos of teachers working in traditional and collaborative classroom settings. First, teaching behaviors were identified in both settings. Next, those qualitative data were quantified by assigning numerical values to certain attributes, to perform statistical analysis. The result enabled researchers to compare teaching behaviors between traditional and collaborative classroom formats. The research team didn't find significant differences in the teaching behaviors between the two classroom settings. They state, "Teachers who use collaborative/cooperative learning will do that no matter how prohibitive the classroom design", and vice versa [343]

Publication type: Journal article
Study type: Experimental study
Sample: 2 classrooms
Duration: Single point in time
Age or developmental stage: University students

Cotner, S., Loper, J., Walker, J. D., Brooks, D. C., Cotner, B. S., Loper, J., Walker, J. D., & Brooks, D. C. (2016). Classrooms Worth It ? " It's Not You, It's the Room" - Are the High-Tech, *Active Learnin.* 42(6), 82–88.

In this paper the authors analyze student performance between tradition classrooms (lecture halls) and "Active Learning Classrooms", which incorporate more high-tech functions as well as more open-plan, decentralized learning spaces (i.e. several small tables instead of 100+ desks facing the front). Biology classes as the University of Minnesota were used as test subjects. Using student high school ACT scores, the researchers predicted student performance in biology classes; then using the final grades in the biology class, researchers could determine, all other things being equal, if the classroom/learning environment led to higher scores in either of the rooms. The study found that students in ALC's outperformed those students in traditional classrooms. This was true even when students in traditional classrooms initially had better ACT scores [334.]

Publication type: Journal article
Study type: Field study
Sample: 161 students (ALC) and 102 students (traditional classroom)
Duration: duration of one course
Age or developmental stage: 19 years old

Folkins, W., Friberg, J. C., & Cesarini, P. a. (2015). University Classroom Design Principles to Facilitate Learning The Instructor as Advocate. *Planning for Higher Education Journal,* 43(March), 1–18.

The authors highlight several spatial and technological attributes of classroom design in higher education facilities. The authors cite a number of research articles that form the basis of their main points and arguments. They summarize the design attributes that architects for higher education facilities should consider. 1) Seating should be flexible and movable, 2) There should be space for the instructor to move around and visit different groups of students, 3) Students in groups should have a way to "report" to the rest of the class (physically and via technology), 4) There should be a clear focal point in the room with good sight lines, 5) Acoustical considerations are important - instructors should be able to address the class from any point, 6) Access into and out of the classroom should be easy, 7) There should be congregation space outside the room for before and after class informal meetings, 8) Simple zoned and adjustable lighting works well, 9) Windows are "not the enemy" - rather than being a distraction, windows provide a welcoming atmosphere and give access to daylight, which is shown to correlate to improved well-being and performance, though issues of glare should be prevented [356].

Publication type: Article
Study type: Literature review - nonsystematic

Eickholt, J., Jogiparthi, V., Seeling, P., Hinton, Q., & Johnson, M. (2019). Supporting project-based learning through economical and flexible learning spaces. *Education Sciences,* 9(3). https://doi.org/10.3390/educsci9030212

The primary purpose of this paper was to determine whether Practical Active Learning Stations (PALS) or Active Learning Classrooms (ALCs) had a similar impact on student learning as ALCs, especially when compared to traditional classrooms as the control. PALS are more economical than ALCs. Researchers selected students in each of the three classroom environments at an undisclosed Midwestern US university. After completing their project-based assignments, students were given a survey to determine the effectiveness of their classroom environments. Some students were also selected to participate in a focus group to give more detailed information on their experience. Both the PALS and ALC performed better than the traditional classroom. In fact, students in the PALS environment gave scores on par with the ALC. While some expensive technology in the ALC was helpful in some cases, the most important qualities of the PALS were the hardware and non-technology attributes, like clustered student tables that enabled group work (versus individual student desks facing the instructor), and ability to share work via whiteboards or shared computer hardware [337].

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 92 students divided in 4 class sections
Duration: One academic year (2 semstres)
Age or developmental stage: University students

Guardino, C. A., & Fullerton, E. (2010). Changing Behaviors by Changing the Classroom Environment. *TEACHING Exceptional Children,* 42(6), 8–13. https://doi.org/10.1177/004005991004200601

In this case study, Guardino et al. explored the influence of classroom arrangements on student engagement and disruptive behavior. The article describes an intervention in one fourth grade classroom, where the researchers worked side by side with the teacher. The study was developed in 2 phases. First, they performed observations in a conventional classroom and rated student engagement and disruption based on a preset scale. The, they talked to the teacher and performed a modification of the seating arrangement, creating group space, adding organizational materials, creating clear pathways adding plants and posters, and providing chair bags for supplies. They found that the intervention was effective to increase student engagement and decrease disruptive behavior during the first part of the lesson. However, their findings were not consistent by the end of the intervention as students' disruptive behavior began to increase again. [329]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: One classroom
Duration: Two classes
Age or developmental stage: Fourth grade

Lam, E. W. M., Chan, D. W. M., & Wong, I. (2019). The architecture of built pedagogy for active learning-a case study of a university campus in Hong Kong. *Buildings*, *9*(11), 1–13. https://doi.org/10.3390/buildings9110230

Using a survey and factorial analysis, the authors of this study identified six factors that define the architecture of built pedagogy for active learning. Active learning requires collaborative learning and teamwork spaces that facilitate the interactions between teachers and students. Built pedagogy refers to a certain type of architecture that responds to a particular type of pedagogy. They identified four essential categories of built pedagogy: modern technologies, space design, comfort and safety, and esthetics, and used them develop their survey with 13 principles nested under these categories. The final six factors that they extracted from the survey to design classrooms for active learning are: Versatility if learning space, Interior design and learning environment, Modern IT/AV Technologies, Interior lighting, comfortable furniture and acoustic design and interior temperature. [330]

Publication type: Journal article
Study type: Research Study
Sample: 410 students
Duration: Single point in time
Age or developmental stage: Undergraduates

Kariippanon, K. E., Cliff, D. P., Ellis, Y. G., Ucci, M., Okely, A. D., & Parrish, A. M. (2021). School Flexible Learning Spaces, Student Movement Behavior and Educational Outcomes among Adolescents: A Mixed-Methods Systematic Review. *Journal of School Health*, 91(2), 133–145. https://doi.org/10.1111/josh.12984

In this review the authors summarize the available evidence on the effects of flexible learning spaces on adolescent student movement behaviors and educational outcomes. To do this, they searched through five different databases and analyzed five quantitative and one qualitative article. They found that students in flexible learning spaces spent less time sitting, more time standing and moving, were more engaged, on-task, self-reported feeling more autonomy, and collaborated and interacted more than students in traditional classrooms. Three of the included studies reported significant associations between flexible learning spaces and improvement in academic performance with moderate effects. They showed that academic results in English, Math, humanities were higher in flexible spaces than traditional classrooms. [331]

Publication type: Journal article
Study type: Literature review
Age or developmental stage: students 12 to 17 years old

Woolner, P., Clark, J., Laing, K., Thomas, U., & Tiplady, L. (2012). Changing Spaces: Preparing Students and Teachers for a New Learning Environment. *Children, Youth and Environments,* 22(1), 52. https://doi.org/10.7721/chilyoutenvi.22.1.0052

Woolner at her colleagues were brought in to observe an experimental week of enquiry-based learning for 8th grade students at a school in the UK, as a "test run" before the school personnel transitioned into a new space. The researchers used photograph annotations, interviews with students, and questionnaires to ascertain student experiences and opinions of the experimental week. Overall, students had a positive experience during the experimental week. Of particular note was the students' preference for more informal, hands-on learning; opportunities to move about and use flexible space (including outdoor space); opportunities for personalization and ownership on their work; and opportunities for more group work. Although the experience was overall positive, the limited nature of the experiment (one week duration, and only involving a portion of the school population) makes it difficult to know whether this type of learning would be successful on a larger scale. The researchers expect that a mix of enquiry-based learning and traditional classroom learning would be optimal.[332]

Publication type: Journal article
Study type: Case study
Sample: 71 questionnaires
Duration: One Week
Age or developmental stage: Eight grade

Wood, P., Warwick, P., & Cox, D. (2013). Developing learning spaces in higher education: An evaluation of experimental spaces at the University of Leicester. *Learning and Teaching,* 5(2), 49–72. https://doi.org/10.3167/latiss.2012.050204

Wood et al, commissioned by the University of Leicester, conducted in-depth social research on the perceptions of students and lecturers of three recently renovated seminar spaces. The three spaces chosen reflect a range of technological upgrades (and thus, a range of budgetary requirements). Initially, a questionnaire was sent to students and lecturers to gauge their preferences in learning environments. Next, interviews and focus groups were conducted with a handful of participants. While technological upgrades were appreciated, most subjects agreed that the two most vital components of the studied spaces were large white boards (either full walls of white board space or traditional mounted white boards) and folding/rolling/movable furniture, for maximum spatial flexibility. Subjects also noted traditional spatial attributes like good daylight, acoustics, views of nature, and thermal comfort. Based on their findings, the authors introduce their DEEP learning space framework, focusing on spaces that are Dynamic, Engaging, Ecological, and Participatory. [333]

Publication type: Journal article
Study type: Field study
Sample: 3 spaces,
Duration: Single point in time
Age or developmental stage: Graduate students

Kariippanon, K. E., Cliff, D. P., Okely, A. D., & Parrish, A. M. (2019). Flexible learning spaces reduce sedentary time in adolescents. *Journal of Science and Medicine in Sport,* 22(8), 918–923. https://doi.org/10.1016/j.jsams.2019.02.007

In this paper, the authors investigate the indirect effect of Flexible Learning Spaces (FLS) on student health by decreasing sedentary sitting time, as compared with traditional classrooms. Researchers had middle school students at nine secondary schools in New South Wales, Australia wear activPAL accelerometers for the duration of a double class period (76 mins) in both FLS and traditional classroom settings. The results of their outputs were then analyzed and compared to their classroom setting. Students in FLS spent less time sitting, had more breaks in sitting, more bouts of intermittent sitting, and fewer bouts of prolonged sitting; they also spent more time standing and stepping. [335]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 121 students
Duration: 76 minutes
Age or developmental stage: 13 years old on average

Talbert, R., & Mor-Avi, A. (2019). A space for learning: An analysis of research on active learning spaces. *Heliyon,* 5(12), e02967. https://doi.org/10.1016/j.heliyon.2019.e02967

In this paper the authors conducted an in-depth literature review, and organized their exploration around 4 central questions regarding Active

Learning Classrooms (ALC's): What effect to ALC's have on 1) measurable metrics of student academic achievement, 2) student engagement, 3) pedagogical practices and behaviors of instructors, and 4) what specific design elements of ALC's contribute to the above effects? While the authors provide numerous specific references to articles, overall, the effect of ALC's on each of the research questions was very positive. They found that ALC's enabled students to connect more directly with each other and with the professor. Taking away the idea of a "front" of the classroom made the ALC's feel more democratic and flexible, enabling students to take more ownership over the space. [336]

Publication type: Journal article
Study type: Literature review

de Borba, G. S., Alves, I. M., & Campagnolo, P. D. B. (2020). How Learning Spaces Can Collaborate with Student Engagement and Enhance Student-Faculty Interaction in Higher Education. *Innovative Higher Education,* 45(1), 51–63. https://doi.org/10.1007/s10755-019-09483-9

The authors state that the purpose of this research is to understand the role of the design of flexible learning spaces in promoting engagement, student-faculty interaction, and improving overall learning. The authors used a mixed-methods approach, with a quantitative survey and more in-depth interviews and focus groups. The research was conducted at a large Jesuit university in Brazil that caters to over 30,000 students. The findings can be summarized in three categories. 1) Even with flexible and well-designed spaces, the quality of the teacher was the most important factor in student engagement. 2) The quality of the physical environment - especially those with flexible elements, like movable furniture, technology, and chalkboards or whiteboards, better facilitated engagement and learning. Also, the design/layout of the classroom must fit the function or activity of the room. 3) Quantitative surveys showed that flexible and well-design spaces correlated to increased student group work, asking questions in class, and to helping classmates understand concepts. [338]

Publication type: Journal article
Study type: Research study
Sample: 1050 questionnaires, 30 students (group interviews)
Duration: Single point in time, 2 hour interviews
Age or developmental stage: University students

Perks, T., Orr, D., & Al-Omari, E. (2016). Classroom Re-design to Facilitate Student Learning: A Case Study of Changes to a University Classroom. *Journal of the Scholarship of Teaching and Learning,* 16(1), 53–68. https://doi.org/10.14434/josotl.v16i1.19190

In this paper the authors assess instructors' and students' perceptions of a flexibility upgrade of a classroom, and its durability in time. They used a typical classroom at an unspecified university as case study. At the start of the research, the classroom could hold up to 60 students, had tables arranged in parallel rows facing the front (even though the tables had wheels and were movable), had no windows, a whiteboard at the front, and fairly modern technology including a SMART board system with projector and

screens. Surveys, focus groups, and observations were conducted in Fall 2012 as the baseline. Before Winter 2013 semester, the room got an upgrade, including: reversing the room orientation, reducing seating to accommodate 40 students, reconfiguring the tables to have small groupings with a central aisle, extending the length of the whiteboard, and painting the two side walls blue, among other changes. Similar qualitative research methods were used in Winter 2013 and Fall 2013 to see how student and instructors' perceptions had changed. Researchers found significantly more positive perceptions among students and instructors in Winter 2013, particularly with regard to the less crowded space, more access to the instructor, and more group work and communication, including sharing ideas via the whiteboard. Interestingly, data from the following semester, Fall 2013, student perceptions had fallen back to a baseline level, though slightly higher than the original data set.[339]

Publication type: Journal article
Study type: Field study
Sample: 151 students (Fall 2013), 127 students (Winter 2013)
Duration: six months, repeated measures
Age or developmental stage: University students

Imms, W., & Byers, T. (2017). Impact of classroom design on teacher pedagogy and student engagement and performance in mathematics. *Learning Environments Research,* 20(1), 139–152. https://doi.org/10.1007/s10984-016-9210-0

The researchers sought to observe and analyze student and instructors' perceptions to classrooms with varying degrees of spatial flexibility, mobility, and technology, as well as effects of these attributes on student performance. Using a primary school in Queensland, Australia as their case study, the researchers identified three classrooms that fit with the purposes of the study - one as the "control" classroom (a traditional setting), one with some small modifications (i.e. "cluster" table arrangements), and the other with more significant modifications (multiple whiteboards, TV screens, and non-traditional furniture. The researchers used student surveys and teacher interviews to obtain quantitative and qualitative data, and student performance metrics lent insight into classrooms' effect on overall performance. Researchers point out that both the longevity of the classroom unit (i.e. students were with the same classroom for the entire year) and retention of the same staff, as well as school willingness to participate, enabled the researchers to control for many variables. In line with many of the other studies, both students and instructors greatly preferred the modified classrooms, especially those with movable furniture, use of whiteboard space, and ability to conduct group work and communicate more openly. Students also tended to perform better in these settings [340].

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 3 classrooms, n=52
Duration: 3 terms (students spent one term in each classroom)
Age or developmental stage: 7th grade

Park, E. L., & Choi, B. K. (2014). Transformation of classroom spaces: traditional versus active learning classroom in colleges. *Higher Education,* 68(5), 749–771. https://doi.org/10.1007/s10734-014-9742-0

In this paper, the researchers sought to compare student perceptions between traditional classrooms and Active Learning Classrooms (ALCs) at SoonSil University in Seoul, South Korea. The researchers first reviewed relevant literature on the evolution of classroom design, and also acknowledged the impact of culture, particularly regarding Asian classrooms vs classrooms in Western cultures. They conducted surveys/questionnaires to gain insight into student perceptions and preferences. Like much of the other research, students tended to prefer more active and flexible learning spaces. Specifically, researchers found what they refer to as "golden zones" and "shadow zones" in traditional classrooms, with golden zones referring to seats or rows in a classroom with the best sighlines, acoustics, and other factors that enable better engagement and learning, vs shadow zones, typically at the back of the room, where the combination of light, sightlines, and acoustics make learning and engagement more difficult. The researchers point out that ALCs effectively diminish shadow zones in the classroom while emphasizing golden zones. [341]

Publication type: Journal article
Study type: Field study
Sample: n = 95 (traditional classroom), n = 133 (ALC classroom)
Duration: Two surveys. Each survey was administered in two different semesters.
Age or developmental stage: University students

Holec, V., & Marynowski, R. (2020). Does it matter where you teach? Insights from a quasi-experimental study of student engagement in an active learning classroom. *Teaching and Learning Inquiry,* 8(2), 140–163. https://doi.org/10.20343/TEACHLEARNINQU.8.2.10

The researchers set out to observe and analyze student self-perceptions of their own growth and engagement in traditional classrooms versus active learning classrooms (ALCs). By controlling for the course and the instructor (both were the same between the two classrooms), researchers could surmise the relative importance that the classroom played on student engagement. The researchers gave students a survey that asked them to self-analyze their own engagement and learning. This was given to students taking the same course with the same instructor, but some took the course in a traditional classroom while others took it in an ALC. Configuration of the classroom had a direct influence of student self-ratings of engagement beyond just the instructor's contribution [342].

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 2 courses: 37 students and 27 students
Duration: One course, single point in time survey
Age or developmental stage: University students

Leers, A. (2017). Collaborative Spaces Transform Teaching , Amplify Learning , and Maximize Resources. September, 1–8.

The author, a principal of architecture firm, sought to obtain qualitative interview data and insight from education professionals into the evolution of classroom learning, from "sage on the stage" to more active, collaborative learning environments. The author and her associates conducted interviews with campus planners and facility directors at universities across the US. There is a growing need for "better utilization and more optimal configuration of teaching spaces". Specifically, the author mentions that in addition to traditional classroom and lecture spaces (which are still used and useful), designers should incorporate 1) small, quiet group study spaces with shared screens/other tech, 2) larger, reconfigurable flat-floor rooms with movable furniture and room dividers, 3) social spaces (ideally with cafe) that serve as lounge and informal study areas, as well as 4) makerspaces for hands-on craft and experimentation [344].

Publication type: Commentary
Study type: Qualitative Research - Journal Article
Duration: Single point in time
Age or developmental stage: University.

Gaum, S. (2019). *Super-Sizing Active Learning time to trade up* . December, 35–46. https://doi.org/10.1073/pnas.1319030111.Read

This article presents a qualitative study conducted by members of an architecture firm. The purpose was to determine main takeaways for active learning in higher education. Using the University of Illinois Chicago as a case study, the authors conducted mixed qualitative research methods, including observation, interviews, and focus groups, to determine the best usage for active learning spaces, keeping in mind budget/economical concerns. The authors summarized their findings with 4 key takeaways: 1) Configure a large classroom to increase student-to-student visibility, encouraging whole class discussions, 2) Refine acoustics so students can clearly hear content no matter where they are located in the room, 3) Inspire student creativity and collaboration with bright and energizing colors in the classroom, 4) Use technological applications during instruction to enhance student engagement.[345]

Publication type: Commentary
Study type: Qualitative Research - Journal Article
Duration: Single point in time
Age or developmental stage: University.

Cort, C., Cort, G., & Williams, R. (2017). *The Challenge of Making Buildings Flexible How to Create Campuses That Adapt to Changing Needs*. September.

In this article the authors aim to make the case for modular building design for campus buildings at universities, as well as other school environments. Using case studies of existing modular buildings at American universities, the authors argue that the shift to more active and flexible learning environments does not "mesh" with the longstanding tradition/philosophy that buildings -

particularly buildings at historic universities - must been seen as concrete, permanent. The authors make the case that modular buildings can be structurally sound, ecologically high performance, and economically viable when it comes to deconstructing and reconstructing. In this way, university buildings can adapt to the 21st century shift in pedagogy toward a more flexible and adaptable environment, by making the buildings flexible and adaptable. [346]

Publication type: Commentary
Study type: Qualitative Research - Journal Article
Duration: Single point in time
Age or developmental stage: University.

Smith, S. T. (2008). *Effects of studio space on Teaching and Learning: two case studies.*

The author conducted a case study of two classes at a university - one with undergraduate students, one with grad students - taking place in a "Studio" style classroom, which used movable furniture, clustered tables vs rows of desks, no clear "front" of the room, whiteboards, other technology. The author's purpose was to observe if the teachers' pedagogy changed as a result of using the Studio classroom and gauge student perceptions. The author conducted four interviews each with the two classes' professors - once at the beginning of the term, then once per month during and at the end of the term. The author also conducted qualitative surveys with the students at the same interval. Overall, reviews of the studio space were positive. One professor completely dove into changing his pedagogy, becoming more interactive and collaborative with students. The other professor did not plan to change her pedagogy and had selected the Studio classroom as a matter of convenience. Nonetheless, the study found that she naturally adapted her pedagogy from a "top-down" approach to a more collaborative, conversational one with students, sitting at tables with them and discussing the material rather than lecturing. The students also gave positive remarks on the Studio classroom in the areas of knowledge gained, communication, and enjoyment [347.]

Publication type: Journal article
Study type: Case study
Sample: 2 classrooms, 2 professors
Duration: One term
Age or developmental stage: University students (undergraduate and graduate)

Thomas, C. L., Pavlechko, G. M., & Cassady, J. C. (2019). An examination of the mediating role of learning space design on the relation between instructor effectiveness and student engagement. *Learning Environments Research,* 22(1), 117–131. https://doi.org/10.1007/s10984-018-9270-4

The authors aimed to investigate the link between the pedagogy implemented in Interactive Learning Spaces (ILS) and their influences on student performance and engagement. The researchers implemented a survey with qualitative and quantitative information to students taking classes in 5 ILS classrooms at Ball State University. The survey was conducted

at the beginning and end of a semester to gauge student perceptions. Researchers found a meaningful link between the design of classrooms - with particular emphasis on technology equipped spaces - and the resulting teacher pedagogy/teaching practice which influenced student engagement and performance. The researchers concluded that from the students' perspective, the ILS design promoted activities that had the largest influence of student engagement and partially explained students' perceptions on the effectiveness of their instructors [348].

Publication type: Journal article
Study type: Field study
Sample: 5 classrooms
Duration: One semester, repeated measures
Age or developmental stage: University students

O'Neill, M. (2013). Limitless learning: creating adaptable environments to support a changing campus. *Planning for Higher Education Journal,* 4(1), 11–27. http://www.scup.org/page/phe

The author first identifies the existing contrast between the past/history of college campuses, and the present/future shift toward technology, adaptability, and flexibility. His goal is to identify ways that architects and planners can design campuses around the future focus on these attributes, while not diminishing the historical significance of many campuses. The author lists several sources in the bibliography, suggesting that his points were formed as somewhat of a review of relevant literature. The author organizes the essay in three main sections: 1) identifying the goals of higher education today, which revolve around serving an increasingly diverse population, incorporating new technology, and fostering community and collaboration; 2) highlighting a singular emerging objective - "limitless learning" - through enabling adaptability in learning spaces, enabling learning by anyone, at any time, by any means, at any place, and 3) identifying the ways that architects and planners can design spaces to tackle these goals. He summarizes a variety of strategies for learning environments, informal social spaces, professor and staff offices, and other spaces. The driving theme is a focus on flexibility, adaptability, and fluidity of space. [350]

Publication type: Article
Study type: Logical argumentation

Kariippanon, K. E., Cliff, D. P., Lancaster, S. L., Okely, A. D., & Parrish, A. M. (2018). Perceived interplay between flexible learning spaces and teaching, learning and student wellbeing. *Learning Environments Research*, 21(3), 301–320. https://doi.org/10.1007/s10984-017-9254-9

The researchers' goal was to identify perceptions and measure well-being signifiers in students and teachers as a result of learning in a flexible environment. They conducted qualitative interviews and focus groups at 8 schools (four primary and four secondary) in Australia, with 12 principals, 35 teachers, and 85 students. The data from transcripts was mined for overarching themes and takeaways. They found that the flexible learning environments enabled improved performance, and well-being metrics,

and also had some challenges. The study includes findings in the following areas, subdivided by theme: 1) Student-centered learning: a) Self-regulation, b) Collaboration, c) Use of technology; 2) Engagement: a) Autonomy, b) Motivation; 3) Teaching & Learning Challenges (i.e. potential disadvantages of flexible learning spaces): a) Increase in possible distraction, b) increase in ambient noise, c) possible problems managing behavior; 4) Social & Emotional Well-being: a) Positive ambience, b) Positive effect on interaction (student-student, student-teacher), c) Inclusiveness; 5) Physical Well-being: a) Better comfort, b) Ergonomics, c) Movement. [351]

Publication type: Journal article,
Study type: Field study
Sample: 8 schools (4 primary and 4 secondary), 12 principals, 35 teachers, and 85 students
Duration: Cross-sectional, Single point in time
Age or developmental stage: Primary and secondary schools

Krajewski, S., & Khoury, M. (2021). Daring spaces: Creating multi-sensory learning environments. *Learning and Teaching,* 14(1), 89–113. https://doi.org/10.3167/latiss.2021.140105

The authors' goal in this study was the gain insight into student and teachers' perceptions of a "soft room" at a university in Australia. Soft rooms refer to classrooms with no or very little hard furniture, moveable/flexible environments, and no front of the room. The researchers identified a specific "soft room" at the university, and to gather their data, they conducted interviews with 8 instructors and a questionnaire with 40 students in 3 classes. They also performed behavior observations in 5 different occasions. Overall, perceptions were mostly positive - students and teachers remarked that they liked the flexible nature of the room, and the "alternative furniture", like beanbag chairs. The technology that was used were portable in nature, like personal ipads - rather than more set-in-stone technology stations. Not scoring as highly were the drab color scheme, somewhat poor daylighting, and location on campus. Some remarked that the room was not as successful as it could be because it was not in a convenient location and was not otherwise living out its fullest potential. [352]

Publication type: Journal article
Study type:, Field study
Sample: 8 instructors, 40 students
Duration: 5 semesters
Age or developmental stage: University

Hynes, M. M., & Hynes, W. J. (2018). If you build it, will they come? Student preferences for Makerspace environments in higher education. *International Journal of Technology and Design Education,* 28(3), 867–883. https://doi.org/10.1007/s10798-017-9412-5

In this paper the authors study a specific category of flexible/collaborative learning environments they call Makerspaces. They conducted a photographic survey, in which students (n=276) at a Midwestern US university - majoring in engineering, art & design, and liberal arts - were shown images of different

Makerspaces and rated different characteristics of the spaces. The photos were rated in terms of their complexity, coherence, mystery, and legibility. The researchers found a range of preferences, with a distinction that engineering majors had different preferences than non-engineering majors. Researchers recommend that Makerspaces be built such that, upon entering, one finds themselves immediately in the "action" (as opposed to entering a quiet lobby); also, spaces should have good sightlines, be easy to navigate, and avoid excess clutter. Finally, designers should also keep in mind the gender gap in Makerspaces, especially among engineering majors, and should design spaces for maximum gender accessibility and equality [353].

Publication type: Journal article
Study type: Research Study
Sample: 276 students
Duration: Single point in time
Age or developmental stage: University students

Blannin, J., Mahat, M., Cleveland, B., Morris, J. E., & Imms, W. (2020). Teachers as embedded practitioner-researchers in innovative learning environments. *Center for Educational Policy Studies Journal,* 10(3), 99–116. https://doi.org/10.26529/cepsj.887

This is a long-term study (still ongoing) that centers its focus around Innovative Learning Environments (ILEs). ILEs are flexible/active learning classrooms with a new student-centered approach to teaching and learning. The research team is implementing a research program wherein educational practitioners conduct ongoing research for a period of three years while actively teaching. The goal is to distill teaching strategies specific to ILE's that are effective in the 21st century. The team identified 8 schools in Australia and New Zealand. Teachers from each school participate as part of the larger research team, and an academic expert act as a liaison between the teachers and the research team. The project is implemented over three years, with each year serving as a different phase. The most important finding thus far is that including active teachers in the research makes a profound difference, instead of having non-teachers conduct classroom research. Although the study is still ongoing, the research team is seeing that the teachers and other education professionals are coming up with new and innovative ways to teach and learn in ILEs [354].

Publication type: Journal article
Study type: Research Study
Sample: Teachers in 8 schools
Duration: 3 years

Ramsay, C. M., Robert, J., & Sparrow, J. (2019). Promoting Pedagogical Agility in Learning Spaces: Toward a Comprehensive Framework of Faculty Support and Innovation. *Journal of Teaching and Learning with Technology,* 8(1), 60–75. https://doi.org/10.14434/jotlt.v8i1.26747

The researchers make the case that adaptable, flexible, technology-enabled classrooms are imporant in 21st century learning environments - but that just as important is care and support of the teaching staff using those classrooms. After first presenting their thesis argument, the researchers

describe a case study of a recently renovated active/flexible classroom on the Penn State campus, called the "Bluebox". The case study consisted of mixed methods research, including interviews and focus groups with teachers and students, behavior observation, active drawing exercises, and video and audio recording. The Bluebox renovation brought the max student capacity down from 100 to 44, thus increasing the available square footage per student, stationary desks were replaced with furniture that as movable and of differing heights, power outlets were plentiful, movable white boards and writable walls were abundant, various screens and other technology was available, and other adaptable measures were implemented. Beyond the physical manifestations that the renovation included, the researchers point out that a holistic agility/adaptability was implemented, with adaptable and ongoing staff support and training. In this way, teachers were not left sticking to "what they knew" when it came to teaching in this new environment, but rather were supported to adapt their pedagogies to best take advantage of the new room. [355]

Publication type: Journal article
Study type: Case study
Sample: one classroom
Duration: 4 semesters
Age or developmental stage: University

Buchanan, S. (2012). Designing the Research Commons: Classical Models for School Libraries. *School Libraries Worldwide,* 18(1), 56.

The author uses literature on both library architecture as well as the classical history of libraries to make the case for a movement toward open, collaborative learning commons in schools, rather than the existing regimented and partitioned school libraries of the recent past. The author makes the case, that school designers, librarians, teacher colleagues, school principals, and other stakeholders should not only get "on the bandwagon" in transitioning from the partitioned libraries of the recent past - but should take historical precedent from Classical Roman and Greek history in the design of collaborative and communal learning spaces of those eras. The author presents the argument that today's trend toward open, collaborative, flexible spaces in school library/commons design - combined with the ubiquity of the Internet and globalization - mirrors the open common spaces of the Ancient past. [357]

Publication type: Journal article
Study type: Literature review

Schechter, C., & Ganon, S. (2012). Learning from success: Exploring the sustainability of a collaborative learning initiative. *Journal of Educational Administration,* 50(6), 732–752. https://doi.org/10.1108/09578231211264667

The authors set out to study teachers' and principals' perceptions of the sustainability of collaborative learning concepts. They point out that, over the last several decades, many different kinds of innovative pedagogical and/or architectural models have come about, only to fade from use after a few

years. The authors present a model called Collective Learning from Success (CLS), whereby research is conducted to determine the sustainability of a collaborative model. Using Israeli schools as their case studies, researchers conducted focus groups and in-depth interviews with 37 teachers and 8 principals. This qualitative research was then analyzed to determine common themes of sustainability in the practice of collaborative, flexible, and active learning environments. Six primary themes/factors emerged as a result of the research: 1) superintendent's role, 2) principal's role, 3) need for structured learning setting, 4) burden added to teachers' workload, 5) overuse of theory and underuse of practice, and 6) congruence with school agenda. [358]

Publication type: Journal article
Study type: Research Study
Sample: 37 teachers and 8 principals
Duration: Single point in time

Gibau, G. S., Kissel, F., & Labode, M. (2019). Starting with the Space: Integrating Learning Spaces and Technologies. *Journal of Teaching and Learning with Technology,* 8(1), 17–32. https://doi.org/10.14434/jotlt.v8i1.26743

This paper studies how university professors use the physical space to plan the curricula of their courses, and how this varies depending on the level of flexibility of space and the availability of technology, classified as "high" technology (screen sharing capabilities, software) and "low" technology (movable furniture, whiteboards, etc). The researchers conducted a case study of a series of anthropology courses at Indiana University. The professors involved in the study worked in a variety of classroom settings, including traditional lecture rooms, more flexible active learning classrooms, and spaces outside the classrooms, specifically museums (given that the classes were focused on anthropology). They found that the spaces that involved more active learning - the active learning classrooms and museum field trips - instigated deeper learning possibilities for students. The researchers pointed out that the "high" technology capabilities, which can come at a heavy cost to institutions - were not the main drivers for deeper learning, but were rather a tool to supplement other more impactful attributes, such as movable furniture, discussion-based learning environments, and collaboration. [359]

Publication type: Journal article
Study type: Case study
Sample: 3 courses, n = 25 students
Duration: One semester
Age or developmental stage: University students

Lo, C. K. (2018). Grounding the flipped classroom approach in the foundations of educational technology. *Educational Technology Research and Development*, 66(3), 793–811. https://doi.org/10.1007/s11423-018-9578-x

The author reviews the literature on flipped classrooms and develops a framework to expand the concept to the whole school. He organizes the discussion into the Spector's six pillars for educational technology, which are communication, interaction, environment, culture, instruction, and learning. Then, the author makes ten recommendations to schools and institutions

hoping to expand the use of the flipped classroom model based on the pillars: A) Communication: 1) Introduce the flipped classroom approach to students and obtain parental consent, 2) Use cognitive theory of multimedia learning to inform the production of instructional videos; B) Interaction: 3) Create a discussion forum for online interactions, 4) Provide online quizzes on video lectures with computerized feedback; C) Environment: 5) Provide human resources and technical resources to support flipped classroom practices, 6) Adopt a school/faculty-wide approach to flipped classroom practices; D) Culture: 7) Cultivate a classroom culture for learner centered instruction; E) Instruction: 8) Utilize established models as the framework for flipped classroom design; F) Learning: 9) Provide optimally challenging learning tasks with instructor's guidance, 10) Use peer-assisted learning approaches during class meetings.[360]

Publication type: Journal article
Study type: Theory development

Martinez-Maldonado, R. (2019). A handheld classroom dashboard: Teachers' perspectives on the use of real-time collaborative learning analytics. *International Journal of Computer-Supported Collaborative Learning,* 14(3), 383–411. https://doi.org/10.1007/s11412-019-09308-z

This paper discusses Computer-Supported Collaborative Learning (CSCL) classrooms, and specifically the use of a handheld dashboard that would inform the instructor of student progress in real-time. The research aims to assess teachers' perceptions of this technology, and ways that real-time dashboards such as these can be used to ensure that students are staying on topic and can get instructor assistance promptly when needed. The study involved four teachers conducting 72 classroom sessions with 150 students during a 10-week term at a university. The researchers used observation and qualitative interviews with teachers to determine the answers to their research questions. The teachers had mostly positive feedback on the handheld dashboards; they were able to quickly respond to student questions or issues, and to make sure students were staying on task in real time. They also found some drawbacks in the technology like a natural incompleteness of classroom data since performance metrics were not included. They found that it was difficult to assess progress on students. Finally, they found a drawback from the immediate response of teachers, as it prevents the possibility of students working together to solve a problem without teacher help. [361]

Publication type: Journal article
Study type: Field study
Sample: 72 sessions, 150 students, 4 teachers
Duration: 10 weeks
Age or developmental stage: University students

de Silva, C. R., Chigona, A., & Adendorff, S. A. (2016). Technology integration: Exploring interactive whiteboards as dialogic spaces in the foundation phase classroom. *Turkish Online Journal of Educational Technology*, 15(3), 141–150.

This paper studies how interactive whiteboards (IWBs) are used in

Foundation Phase classrooms (for younger children), as part of a larger study exploring how teachers make use of technology as a pedagogical tool. The researchers present relevant literature, and then describe a case study of a Foundation Phase school in Cape Town, South Africa. The research consisted of observation and interviews with teachers. Researchers found that there was a gap between availability of IWBs and effective use of the technology in delivering the pedagogy and generating reciprocal dialogue with the students. The paper makes an argument that IWBs can be better incorporated at the Foundation Phase to encourage participation and spur more growth via collaborative learning; they argue that Foundation Phase teachers can and should be given training to use this technology at this early phase. [362]

Publication type: Journal article
Study type: Case study
Sample: 6 teachers
Duration: 18 months
Age or developmental stage: Teachers of foundation phase classrooms (younger students)

Higgins, S. E., Mercier, E., Burd, E., & Hatch, A. (2011). Multi-touch tables and the relationship with collaborative classroom pedagogies: A synthetic review. *International Journal of Computer-Supported Collaborative Learning*, 6(4), 515–538. https://doi.org/10.1007/s11412-011-9131-y

In this paper, the authors aim to use a thorough review of literature to dissect the technological innovation of the interactive tablet/surface as used within a collaborative setting. They describe the technological abilities of these surfaces and place them within the shifting pedagogy of the modern classroom. The researchers conducted a thorough review including over 100 sources. The researchers make a solid case for the possibilities afforded by the technological innovation of collaborative tablets/surfaces. They divide the technology into a three-pronged typology, with sub-categories, as follows: 1) Surface (Geometry, Display Type), 2) Touch (Touch Sensing, Tangibles, Styli), and 3) Connectivity (Local, Remote). The authors note that the main disadvantages of multi-touch tables and surfaces is their cost, both in terms of capital as well as the dearth of support and technological fluency of teachers required to make adequate use of the technology. [363]

Publication type: Journal article
Study type: Literature review
Sample: over 100 sources

Ivory, D.M. (2011). The Impact of Dynamic Furniture on Classroom Performance: A Pilot Study.

Ivory addresses how dynamic furniture can impact the classroom performance of students. The study involved 19 students in second grade. Measurements were taken on the attention, work neatness, and work completion of the students. The three different dynamic furniture options were: Zuma chairs~, Disc'O'Sits~ (inflated seat cushions), and standing desks with the Original

FootFidget~. A daily self-report was taken on attention behaviors and perceptions of the furniture. The study found that overall, no one type of furniture proved the same effect on learning, attention, work neatness, and work completion for all the students. The study found that the personal traits and characteristics of students would potentially be used to pick the best furniture for them to create the best environment for them specifically. Even within one category of furniture, students responded differently based on their learning needs and abilities. The self-reported data also showed that some students thought there were able to finish their work better, but their quality of work decreased. [365]

Publication type: Paper
Study type: Pilot Study
Sample: 19 students
Duration: Longitudinal
Age or developmental stage: 2nd Grade

Purwaningrum, L., Funatsu, K., Xiong, J., Rosyidi, C. N., & Muraki, S. (2015). Effect of Furniture Weight on Carrying, Lifting, and Turning of Chairs and Desks among Elementary School Children. *PloS One*, 10(6), e0128843. https://doi.org/10.1371/journal.pone.0128843

Purwaningrum, Funatsu, Xiong, Rosyidi, and Muraki address how the movement of furniture is affected by the weight of furniture for students to create a learning environment that they want. The study involved 42 children in school that were six to nine years old. The study involved 25 Japanese students and 17 Indonesian students. There were two types of Japanese chairs, A weighing 3.2 kg, and B weighing 3,9 kg. There was one type of Indonesian chair, C, weighing 5.0 k. There were two types of desks 58 and 68 cm tall. The study found that the Indonesian chairs took longer, significantly, to carry the two Japanese chairs. There was a negative relationship that was seen significantly between the task time for Chairs B and C and age, but not for chair A. The ability to succeed in turning and lighting the chair decreased as age decreased and chair weight increased. The students that were ages six and lower had low success rates with all the furniture. [366]

Publication type: Journal Article
Study type: Case Study
Sample: 42 students
Duration: Longitudinal, Cross-sectional
Age or developmental stage: 6 to 9 Years Old

Domljan, D., Grbac, I., Hadina , J. 2008). Classroom furniture dimensions and anthropometric measures in primary school. Collegium Antropologicum, 32(1), 257–265. 10.1016/j.apergo.2003.11.002

Domljan, Grbac, and Hadina address how students are affected by the dimensions of themselves compared to the dimensions of school chairs. The study involved students from grades 1 to grade 8 in primary school. The study also involved the chairs they used in the classrooms and the measurements of the chairs were compared to the measurements of the students. The fit

of the chairs was measured to determine the best efficiency and the best posture for students. There were 566 students from three primary schools. The students were from Zagreb, Croatia and there were two different types of dimensions. The study found that there is not appropriate furniture in classrooms for students in Croatia for most schools. The study also recommends that furniture be made to be adjustable for students and that the four heights and adjustable furniture should be sued in Croatian schools. The study also recommends the promotion of active sitting behavior that is appropriate for students. [367]

Publication type: Journal Article
Study type: Case Study
Sample: 566 students
Duration: Longitudinal, Cross-sectional
Age or developmental stage: 1st to 8th Grade

Parvez, M., Parvin, F., Shahriar, M.M., & Kibria, G. (2018). Design of Ergonomically Fit Classroom Furniture for Primary Schools of Bangladesh. *The Journal of Engineering*, 2018, 1-9. https://doi.org/10.1155/2018/3543610

Parvez, Parvin, Shahriar, and Kibria address the fit of furniture compares to students based on the ability that it can create discomforts and musculoskeletal disorders. The study involved 10 primary schools that a survey was conducted at in Khulna, Bangladesh. The anthropometric measurements were taken from 300 students that participated in the study and attended the 10 primary schools. The anthropometric measurements and furniture dimensions were compared to find mismatches that could affect students. The survey found that there was a significant mismatch between the student anthropometric measurements and the furniture measurements. The survey also found that the furniture used was too large when compared to students. Specifically, the desk height of the furniture was too high for the students. The study also found that the seat height was too high for students. The study also found that seat width was too small for the students to sit comfortably on. The study proposed a furniture dimension that required the mismatch measurements from 90% to 10%. [368]

Publication type: Journal Article
Study type: Research Article/Survey
Sample: 10 schools
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Primary

Benden, M. , Pickens, A. , Shipp, E. , Perry, J. and Schneider, D. (2013) Evaluating a school based childhood obesity intervention for posture and comfort. *Health*, 5, 54-60. doi:10.4236/health.2013.58A3008.

Benden, Pickens, Shipp, Perry, and Schneider address how posture and discomfort of students are changed or unchanged when comparing traditional seating and standing-based desks and the health effects. The study involved 42 elementary students in four classrooms. The Portable Ergonomic Observation method was used to assess their posture in the

four classrooms. Two classrooms had stand-based workstations for fifteen students and two classrooms had traditional seated workstations with 27 students. Measurements and assessments were taken three times for a two-minute search for observation. The study found that there was no significant difference between the two groups. The study found that children using stand-biased workstations had less discomfort overall. The study also found that the stand-biased desks the no create any additional ergonomic issues and provided another way to increase caloric expenditure. The study also states that another study needs to be done with older children and a large sample through the entire school day and not for such a short period. [369]

Publication type: Journal Article
Study type: Research Study
Sample: 42 students
Duration: Single Point in Time, 2 minutes each time
Age or developmental stage: Elementary

Parcells, C., Stommel, M., & Hubbard, R. P. (1999). Mismatch of classroom furniture and student body dimensions: empirical findings and health implications. *The Journal of adolescent health : official publication of the Society for Adolescent Medicine*, 24(4), 265–273. https://doi.org/10.1016/s1054-139x(98)00113-x

Parcells, Stommel, and Hubbard address how there is a potential mismatch between the dimensions of classroom furniture and the body dimensions of students. The study involved 74 sixths through eighth-graders from a Michigan school district. The ages of the students were 10 years to 14 years old. The anthropometric measurements were taken during physical education classes in one session. The measurements involved elbow height, shoulder height, upper arm length, knee height, popliteal height, stature, and buttock-popliteal length. Measurements were also taken of the furniture for the three styles of desks and three styles of chairs in the classrooms. The study found that there was a significant degree of mismatch between the classroom furniture dimensions and the student's bodily dimensions. The study also found that less than 20% of the students in the classrooms can find acceptable chair desk combinations in the classrooms. The majority of students sat in desks that were too height and with chairs that were too hair or too deep. [370]

Publication type: Journal Article
Study type: Research Study
Sample: 74 students
Duration: Single Point in Time, One Session
Age or developmental stage: Sixth to Eight Grade

Starkey, L., Leggett, V., Anslow, C., Ackley, A. (2021), The Use of Furniture in a Student-Centred Primary School Learning Environment. *NZ J Educ Stud* 56, 61–79. https://doi.org/10.1007/s40841-020-00187-9

Starkey, Leggett, Anslow, and Ackley address how furniture is used to create a flexible learning environment. The study involved study group interviews and teacher interviews from one school in New Zealand. The learning environment was three separate cellular classrooms that had been changed

to be a flexible open-plan learning space. There were three teachers and two teacher aides in the classroom space. There were 90 students ages 9 to 11 years old in the space that moved between three classrooms. The study found that students use furniture for different and new purposes. The study also found that their furniture use was influenced by students, environment, furniture design, curriculum, teachers, and competence. Students became aware of how they could use the furniture differently to meet their educational needs. The use of a large space as a classroom creates the ability for environmental competence to be explained to the teachers and students and become a part of the teaching and learning. [371]

Publication type: Journal Article
Study type: Research Study
Sample: 74 students
Duration: Longitudinal
Age or developmental stage: 9 to 11 Years Old

Knight, G., & Noyes, J. (1999). Children's behaviour and the design of school furniture. *Ergonomics*, 42(5), 747–760. https://doi.org/10.1080/001401399185423

Knight and Noyes address how furniture impacts behavior due to the design of furniture and furniture industries. Health and performance were large focuses. The literature review involved texts that address furniture and its effect on children. There was a focus on the measurements of children's major problems associated with school furniture, the anthropometry and egomaniacs, criteria and standards, material, and furniture type. Chairs and desks are considered some of the most important parts of a classroom yet rarely accurately fit students and their dimensions. The use of ergonomic furniture at primary schools allowed for the decrease in back pain and musculoskeletal disorders. The use of chairs and desk are to support students and teachers while also allowing them to write, draw, and work on a surface that allows them to learn. The criteria for the standardization of furniture needs to be reconsidered and there should be furniture that fits, is adjustable, easily maintained, comfortable, durable, provides safety, stability, and creates the best learning environment for students. [372]

Publication type: Journal Article
Study type: Experimental Study/Literature Review
Sample: NA
Duration: Cross-sectional
Age or developmental stage: School Children

Fidelis, O., Ogunlade, B., Sa, A., & Adukwu, O. (2018). ERGONOMIC ANALYSIS OF CLASSROOM FURNITURE IN A NIGERIAN UNIVERSITY. *Nigerian Journal of Technology*, 37, 1154-1161. https://doi.org/10.4314/njt.v37i4.40

Fidelis, Ogunlade, Adelakun, and Adukwu address how ergonomically suitable classroom furniture is at the Federal University of Technology, Akure, Nigeria. The study involved 261 students that were randomly selected. There were 128 females and 133 males involved in the study. The study involved the measurement of the dimensions for the furniture to be recorded and analyzed.

The study found that there was a significant level of mismatch between the anthropometric measures of students and the furniture and its dimensions. The study also found that 37.2% and 31.8% of the students in the study had seats that were too low or too high for their anthropometric measures. 50.6% and 18.4% of the students in the study used seats that were too shallow and too deep in their anthropometric measures. The study also found that 90% of the students used desk that was too high, 2% used desks that were too low, and 7% used desks that fit their anthropometric measures. [373]

Publication type: Journal Article
Study type: Case Study
Sample: 261 Students
Duration: Cross-sectional, Single Point in Time
Age or developmental stage: University

Castellucci, H. I., Arezes, P. M., Molenbroek, J. F., de Bruin, R., & Viviani, C. (2017). The influence of school furniture on students' performance and physical responses: results of a systematic review. *Ergonomics*, 60(1), 93–110. https://doi.org/10.1080/00140139.2016.1170889

Castellucci, Arezes, Molenbroek, de Bruin, and Viviani address students' physical responses and performance are affected by the design and dimensions of school furniture. The study involved case studies, experiments, research, and papers that involve school furniture design, school furniture dimensions, methodology, and results of the case study. There were 581 registries in the searches. 25 studies were reviewed. The study and review found that in the review studies there were 64% presenting positive results, which means proven effects. The study also found that there were 24% that presented no change/effect or negative effects. The 12% remaining showed an unclear effect. To improve students' physical responses, it was found that furniture dimensions and students' anthropometric characteristics need to be identified and measured. The study also found that high furniture, sit-stand furniture, and tilt tables and seats create positive effects. The review study also found that further research needs to be done. [374]

Publication type: Journal Article
Study type: Systemic Review
Sample: 581 registries
Duration: Cross-sectional
Age or developmental stage: Students

Alibegovi~, A., Hadžiomerovi~, A., Pašali~, A., Domljan, D. (2020). School furniture ergonomics in prevention of pupils' poor sitting posture. DRVNA INDUSTRIJA, 71(1), 89-99. https://doi.org/10.5552/drvind.2020.1920

Alibegovi~, Hadžiomerovi~, Pašali~, and Domljan address how unmatched school furniture affects students, their development, posture, and health problems. The paper involved a review of previous studies, papers, research, and scientific literature about the health problems, posture, and development of students due to furniture that is unmatched in classrooms. The review involved a comparison of 10 appears in Finland, Greece, Croatia, Slovenia, Nigeria, Brazil, Iran, Belgium, United Kingdom, and India. The papers were

from 2004 to 2007 and were from multiple databases. The review found that there is inadequate posture of students due to furniture in the school. The review also found that there is a mismatch between the students' body dimensions and furniture dimensions. The chairs are too high or too low for students which creates unwanted posture and health effects that are musculoskeletal. The review also found that desks and chairs can be too wide or deep that creates issues with concentration because of back pain. The study concludes that the effects found in this review can be used to create guidelines for furniture in classrooms. [375]

Publication type: Journal Article
Study type: Review Paper
Sample: 10 texts
Duration: Cross-sectional
Age or developmental stage: Students

Gilavand, A. (2016). The Impact of Educational Furniture of Schools on Learning and Academic Achievement of Students at Elementary Level. *International Journal of Medical Research & Health Sciences*, 5(7S), 343-348.

Gilzavand addresses how educational furniture impacts the learning and performance of students in elementary schools. The study found that in the city of Ahvaz, in the southwest of the Islamic Republic of Iran in the years 2015-2016 students were selected to analyze the impacts of furniture in schools. 210 students were selected randomly to be a part of the study. Appropriate allocation and questionaries were randomly given to students. Hermance's achievement motivation questionnaire, researchers instructed questionnaire, and interviews allowed for the measurement of the effects. The data were analyzed using SPSS-21 software. The study found that when there is educational furniture that is considered appropriate in classrooms there is a positive impact on learning for students in elementary schools. The study also found that furniture impacts student learning and effectiveness, which determines their academic achievements. The study suggests that tables and benches should be given measurements based on existing anthropometric dimensions databases that allow for the standardization and correction of educational furniture for students. [376]

Publication type: Journal Article
Study type: Cross-sectional Study
Sample: 210 students
Duration: Cross-sectional, Longitudinal, 1 Year
Age or developmental stage: Elementary

Benden, M. E., Zhao, H., Jeffrey, C. E., Wendel, M. L., & Blake, J. J. (2014). The evaluation of the impact of a stand-biased desk on energy expenditure and physical activity for elementary school students. *International journal of environmental research and public health*, 11(9), 9361–9375. https://doi.org/10.3390/ijerph110909361

Benden, Zhao, Jeffrey, Wendel, and Blake address how energy expenditure and physical activity are affected by stand-biased desks for elementary students. The study used three elementary schools in central Texas. There were 480 students involved from 24 classrooms and 387 of them offered to

do a data collection that lasted a week during the spring and fall semesters. Data measurements were taken with a Sensewear armband that measured step count and energy expenditure. The study found that the students in classrooms with seated desks had significantly lower energy expenditures. The study also found that the students in classrooms with seated desks had a lower step count during standard lecture time compared to the students in stand-biased classrooms. The study also found that a standing desk had an energy expenditure that was 0.16 kcal/min higher in the fall semester. The study also found that the standing desk had an energy expenditure of 0.08 kcal/min in the spring semester. [377]

Publication type: Journal Article
Study type: Case Study
Sample: 480 students, 387 in study
Duration: Cross-sectional, Longitudinal, 2 weeks during two semesters
Age or developmental stage: Elementary

MohdAzuan, K., Hashim, Z., Tamrin, S.B., Ali, N.A., M.N., M.A., & Ismail, S.A. (2010). Neck, upper back and lower back pain and associated risk factors among primary school children. *Journal of Applied Sciences*, 10, 431-435. https://dx.doi.org/10.3923/jas.2010.431.435

Mohd, Zailina, Shamsul, Nurul, Mohd, and Syazwan address how classroom furniture affects pain in elementary school children, specifically in their lower back, upper back, and neck. The study involved 100 children from two primary schools in Malaysia. The students that were Year 2 and 5 were given questionnaires on their previous skeletal inquiries, satisfaction withs school furniture, musculoskeletal pain/discomfort, and their background to measure the data with. The study found that the most prevalent musculoskeletal disorder was neck pain. the neck pain had a periodic prevalence of 15.3% and a lifetime prevalence of 33%. The upper back pain had a lifetime prevalence of 20.2% and a periodic prevalence of 9.1%. The low back pain had a lifetime prevalence of 13.1% and a periodic prevalence of 8.1%. The neck pain in students was found to significantly affect the satisfaction with classroom furniture, satisfaction with desk heigh, and satisfaction with backrest shape.[379]

Publication type: Journal Article
Study type: Cross-sectional Study
Sample: 100 students
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Primary

Domljan, D., Vlaovi~, Z., & Grbac, I. (2010). *Pupils' working postures in primary school classrooms. Periodicum Biologorum,* 112, 39-45. http://hrcak.srce.hr/file/80494

Domljan, Vlaovi~, and Grbac address how the usage of tables and chairs in classrooms affects behavior, movements, and activities in classrooms of primary school students. The study involved 18 students. The students were from 2nd to 8th grade at a school in Zagreb, Croatia. The students were measured on how they interacted with space because of furniture, their behaviors, and activities with video recordings. Researchers examined video recordings to measure and analyze how students were or were not

affected. The study found that there were 43 characteristic postures and semi-postures in the four main groups that were recorded. The study also found that there was a major difference between how students interacted with the task chair and table because of gender, daytime, studied subjects, tasks, teacher's behavior, and age. The study found that school furniture and its design need to take into the age and anthropometric measurements of children as well as their postures. [380]

Publication type: Journal Article
Study type: Research Study
Sample: 18 students
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Primary, 2nd to 8th Grade

Haghighi, M. M., & Jusan, M. B. M. (2015). The impact of classroom settings on students' seat-selection and academic performance. *Indoor and Built Environment*, 24(2), 280–288. https://doi.org/10.1177/1420326X13509394

Haghighi and Jusan address how classroom design impacts students' performance and their choice of seat selection. The methods involved in this quantitative study were 370 students from Shiraz, Iran that attend public high schools. Thirteen high schools were chosen and students at those schools were given questionnaires. The scale and seating of classrooms were very similar and were measured in terms of design, flexibility in space, and abilities. The measurements were taken on performance with grades, seat selection, gender, motivation, and classroom environments. Students were given an architectural questionnaire and a motivation questionnaire. The quantitative study found that when spaces had semi-flexible features, there was an influence for boys in their performance while selecting a seat. The study also found that aural factors and visual factors were effective in increasing learners' performance with seating for boy and girl students. The study also found that achievement motivation affected learner performance. [381]

Publication type: Journal Article
Study type: Quantitative Study
Sample: 370 Students
Duration: Cross-sectional, Longitudinal

Age or developmental stage: High School

Pedagogy

Aidinopoulou, V., & Sampson, D. G. (2017). An action research study from implementing the flipped classroom model in primary school history teaching and learning. *Educational Technology and Society*, 20(1), 237–247.

In this paper, the authors study the effectiveness of the flipped classroom (FC) model in a primary educational setting in history/social studies, to see if the FC model is effective in those environments. The authors studied two 5th grade classrooms over the course of an entire schoolyear, both studying the same history topic, but one class using the traditional lecture format, and the other using the the FC format. The classrooms were studied using an "action" research method, which involved observation, studying teacher logs, and measuring student performance. The students in the FC classroom showed higher test scores and other performance metrics, including a deeper understanding/critical thinking of the subject, as opposed to simple memorization of certain topics [401].

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 2 classrooms, n = 49 students
Duration: One year
Age or developmental stage: 11 years old, grade 5

Algayres, M., & Triantafyllou, E. (2020). Learning analytics in flipped classrooms: A scoping review. *Electronic Journal of E-Learning*, 18(5), 397–409. https://doi.org/10.34190/JEL.18.5.003

This paper presents a review of the literature of the last decade to observe the overlap between Learning Analytics (LA) in the Flipped Classroom (FC). The researchers acknowledge the relative new concept of FC and discuss how LA can help researchers and educators better identify the strengths and weaknesses of FC for student learning. The researchers reviewed 49 scholarly articles from 2009-2019 that studied LA in the FC model. The authors note that most studies on the FC show positive results in student engagement and performance, especially given the active learning nature of the FC. The authors note that most LA has focused on pre-class student engagement (i.e. with learning the material online) and post-class student performance (i.e. tests and quizzes), with less LA conducted on in-class activities. [399]

Publication type: Journal article
Study type: Literature review
Sample: 49 studies

An, P., Bakker, S., & Eggen, B. (2017). Understanding teachers' routines to inform classroom technology design. *Education and Information Technologies*, 22(4), 1347–1376. https://doi.org/10.1007/s10639-016-9494-9

The researchers set out to study teachers' routines in secondary schools and to determine strategies designers can use to overcome the obstacles presented by them. The researchers identified seven willing participants,

teachers at secondary schools in the Netherlands. A mixed qualitative method study was performed, including observation, individual interviews, and focus groups. The study determined different types of routines and the associated challenges that daily burdens and limitations of teachers' routines on their ability to fully take advantage of 21st century technologies and pedagogies surrounding active learning. Among them are dealing with interruptions from students, making sure all students were engaged in an activity, etc. [403]

Publication type: Journal article
Study type: Research study
Sample: 7 participants
Duration: 1 to 2 weeks
Age or developmental stage: Secondary school Teachers

Baldwin, L., & Sabry, K. (2003). Learning Styles for Interactive Learning Systems. *Innovations in Education and Teaching International*, 40(4), 325–340. https://doi.org/10.1080/1470329032000128369

This study considers the implementation of the Interactive Learning System (ILS) through the lens of student learning styles. Their main goal is to highlight the fact that although flexible learning spaces/ILS's seem to have many benefits, it is important to understand the learning styles of students to best take advantage of flexible learning systems The authors conducted a 44-question learning style survey at a university in the UK during the 2001-2002 schoolyear with 148 students, in order to determine the array of learning styles. There were a range of learning styles, with several weighted toward the Visual and Active learning styles. The authors took the results of the survey to propose the Balanced Learning Design method (BLADE), which aims to supplement the architectural concept of an ILS with a pedagogical framework so that teachers may be best equipped to teach in a way that accommodates a range of learning styles. These styles include Active, Reflective, Sensing, Intuitive, Visual, Verbal, Sequential, and Global (a student will exhibit a combination of these, not just one). The researchers make suggestions for how an ILS might facilitate learning with each one of these styles [398.]

Publication type: Journal article
Study type: Research Study
Sample: 148
Duration: Single point in time
Age or developmental stage: Undergraduate

Browne, S., & Mccluskie, G. (2018). *Campus Renewal: Working With What You ' ve Got*. June, 49–56.

This case study details an updated master plan at Laurentian University in Sudbury, Ontario. The authors discuss a 21st century approach to the master plan that eschews expansion in favor of maximizing flexible spaces and "building in", not out. Through working with key stakeholders at the university, including student groups (English, French, and Indigenous groups), the designers helped bring about an updated campus with 21st century buildings, and plenty of open, flexible, adaptable spaces. The designers highlight five

overarching strategies that are the key outcomes of the case study, and should be considered in other master planning projects: 1) improve teaching spaces (by making them more open and flexible), 2) enhance gathering and study spaces, 3) integrate student services, 4) create a Welcome Centre, 5) support the intellectual milieu, to ensure the goals remained present and real; these goals were enacted with the underlying theme of being "student focused." [397]

Publication type: Article
Study type: Case study
Age or developmental stage: University

Campbell, L. (2020). Teaching in an Inspiring Learning Space: an investigation of the extent to which one school's innovative learning environment has impacted on teachers' pedagogy and practice. *Research Papers in Education*, 35(2), 185–204. https://doi.org/10.1080/02671522.2019.1568526

Campbell addresses how teachers are impacted by differing learning spaces, specifically, on their pedagogy and practice. The methods involved in this research were 66 teachers at a school in Scotland during the 2016-2017 school year. The measurements involved understanding the new learning space which was called Inspiring Learning Space that involved multiple classrooms combined to create one large classroom. Twelve teachers were given a questionnaire that measured their beliefs about how effective the space was for learning, how they planned to teach in the space, and their beliefs about the use of technology in the space. The research found that the Innovative Learning Space was a way to address how to change the "traditional" learning space that involves more collaboration between students and teachers, while also allowing for more movement and choices of teaching and learning. Teachers could work toward creating an engaging way of practicing their skills, while also changing the teachers' pedagogy and ideas on learning. [406]

Publication type: Journal article
Study type: Research Paper
Sample: 12
Duration: Longitudinal, One Year
Age or developmental stage: Secondary

Cleveland, B., & Fisher, K. (2014). The evaluation of physical learning environments: A critical review of the literature. *Learning Environments Research*, 17(1), 1–28. https://doi.org/10.1007/s10984-013-9149-3

In this literature review, the authors discuss the Post-Occupancy Evaluation (POE) as a tool for evaluating the effectiveness of learning environments, namely schools and classrooms. They discuss the advent of POE's in non-residential spaces, and the evolution to school specific POE's. Their intention is to discuss areas where POE's have been beneficial in school design, and areas where the POE can improve. The authors conducted a review of the relevant literature on the overlap of POE's and school design/learning outcomes. They found that overall, POE's have had a significant impact on

the architecture/design of schools and classrooms. The authors point out two primary areas for improvement for future POE's in schools - one involves a multi-disciplinary approach, bringing together educators, architects, human geographers, and environmental psychologists. The other emphasizes the importance of student participation; much of the POE research has focused on educators and other adults, so more student perspectives should be included. [400]

Publication type: Journal article
Study type: Literature review

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education-A systematic literature review. *Thinking Skills and Creativity,* 8(1), 80–91. https://doi.org/10.1016/j.tsc.2012.07.004

In this literature review, the authors looked at 210 pieces of educational, policy, and professional literature relating to creative learning environments, and distilled the information into relevant takeaways particularly for use in Scotland. Papers were selected only for the period between 2005-2011. While the authors note that many of the researched articles were not as useful as hoped, they were still able to distill the information into several important spatial and pedagogical attributes to benefit student learning. These were: flexible use of space and time, availability of appropriate materials; working outside the classroom/school; 'playful' or 'games-bases' approaches with a degree of learner autonomy; respectful relationships between teachers and learners; opportunities for peer collaboration; partnerships with outside agencies; awareness of learners' needs; and non-prescriptive planning. [384]

Publication type: Journal article
Study type: Literature review
Sample: 58 studies

Fisher, T. (2016). Do We Need Classrooms Anymore ? *Planning for Higher Education,* June, 9–12.

The author makes the argument that the idea of the 'classroom' as a specific, physical room in which learning happens may soon be changing altogether, and that the innovations brought by ALCs and the flipped classroom model are merely transitional. Rather than conduct a formal research study, the author makes his argument by looking at the transformation of the working office, which has gone from individual offices and cubicles to more open, collaborative, comfortable spaces in which conversations are had and work is accomplished more flexibly. He also speaks of a class he teaches at his university where students decide each week where the class will meet - and they never select a classroom, but rather open, flexible spaces with comfortable seating, lots of light, and fluidity in movement and conversation. The main takeaway is that designers and educators should begin to move beyond the paradigm that the classroom is a physical room specifically for learning, and become open to the possibility that 'classroom' should be a fluid term applied to many different kinds of spaces. Further, different types of learners will have different "classrooms" - design students may thrive in

an open studio environment; social/intellectual learners in business or law may thrive in a "commons" area with lots of action, conversation, and noise; environmental or nature learners may thrive in outdoor, natural classrooms. 395

Publication type: Article
Study type: Logical argumentation
Age or developmental stage: University

Jenkins, M., Bokosmaty, R., Brown, M., Browne, C., Gao, Q., Hanson, J., & Kupatadze, K. (2017). Enhancing the design and analysis of flipped learning strategies. *Teaching and Learning Inquiry*, 5(1). https://doi.org/10.20343/teachlearninqu.5.1.7

This paper discusses the popularity of the flipped classroom model. The authors situate flipped learning within a pedagogical framework and propose and approach to analyze and design flipped learning strategies. The researchers conduct a thorough literature review on the flipped classroom framework and associated pedagogies. The main finding/result of this literature review is a "Flipped Learning Matrix Model" with two dimensions: content-focused to product-focused, and teacher-led to student-led. The four quadrants of this matrix are: Producing (Teacher-product), Authoring (learner-product), Pursuing (learner-content), and Identifying (teacher-content). 404

Publication type: Journal article
Study type: Literature review

Kokko, A. K., & Hirsto, L. (2021). From physical spaces to learning environments: processes in which physical spaces are transformed into learning environments. *Learning Environments Research,* 24(1), 71–85. https://doi.org/10.1007/s10984-020-09315-0

The authors set out to explore what makes a physical space become a "learning environment". They point out that although a classroom is a well-defined physical setting, a learning environment is a much looser, more philosophical term that could apply to any physical setting, if the conditions for learning are present. The researchers identified two primary schools in Finland that had recently been redesigned and reopened with more flexible learning spaces. One school - the "development school" - had been operational in the new environment for two years, and the other had just opened, with new students and staff. The authors conducted observational research at the two schools for one year, and supplemented the research with teacher focus groups, and more in-depth interviews with principals. The authors identified three main findings 1) Nascent processes, which are made up of three separate interaction processes: teacher-teacher, teacher-student, and student-student. 2) Advanced processes, which are made up of cyclical interactions between the three previously mentioned interaction processes; and 3) barriers and facilitators of change involved both physical and time-oriented structures, from giving teachers adequate time to rest and to plan lessons, to having the most ideal student-teacher ratio for maximum benefit. 385

Publication type: Journal article
Study type: Case study, Theory development
Sample: 2 schools, focus groups with 30 teachers
Duration: One year

Kim, M., Jung, E., de Siqueira, A., & Huber, L. (2016). An Investigation into Effective Pedagogies in a Flipped Classroom: A Case Study. *Journal of Distance Education*, 31(2), 1.

Kim et al. study the in-class, lab segment of a flipped classroom environment in order to gauge effectiveness of the strategy on student learning. The research focused on Merril's (2002) First Principles of Instruction: 1) Task/ Problem-Centered, 2) Activation, 3) Demonstration, 4) Application, 5) Integration. After reviewing the relevant literature, the researchers selected a graduatee course at a large university that had recently switched to a flipped classroom model, with self-paced video lectures available on Canvas and in-person lab activities to supplement the online material. The research involved classroom observation, a survey of students, and instructor interview. Out of the five Principles of Instruction, 'Application' and 'Demonstration' were the two most clearly prevalent in the flipped classroom model, with some 'Integration' and 'Activation'; there was almost no measured evidence of 'Task/Problem-Centered' instruction in the in-class lab sessions. [405]

Publication type: Journal article
Study type: Case study
Sample: one course, 70 students
Duration: one semester
Age or developmental stage: University, graduate

Kim, J. E., Park, H., Jang, M., & Nam, H. (2017). Exploring Flipped Classroom Effects on Second Language Learners' Cognitive Processing. *Foreign Language Annals*, 50(2), 260–284. https://doi.org/10.1111/flan.12260

In this study, the researchers used two second language learning classes -one had a traditional classroom format, the other used the flipped classroom format- in order to gain insight as to how the two compared, specifically in second language learning classes. The researchers conducted qualitative and quantitative research at a Korean university with students of various backgrounds learning Korean as their second language. They conducted questionnaires, behavior observation, and interviews to gain insight into the students' perceptions and participation rates. They also used student performance metrics to determine if there was any difference in performance between the two frameworks. They found little difference in student participation, but the flipped classroom model showed that students had deeper information processing and higher-order reasoning skills than the traditional classroom. [386]

Publication type: Journal article
Study type: Quasi-experimental study
Sample: 2 second language classes (n=26 and n=25)
Duration: One activity in one class

Age or developmental stage: 20 to 21 – University students

Knaub, A. V., Foote, K. T., Henderson, C., Dancy, M., & Beichner, R. J. (2016). Get a room: the role of classroom space in sustained implementation of studio style instruction. *International Journal of STEM Education*, 3(1). https://doi.org/10.1186/s40594-016-0042-3

This paper investigates the results of the implementation of the studio-style instruction called Student-Centered Active Learning Environment with Upside-Down Pedagogies, aka SCALE-UP framework. The researchers conducted in-depth interviews with 21 faculty who had successfully implemented SCALE-UP in their schools. Their interviews focused on four main topics: 1) how these classrooms are initiated, 2) which classroom features are helpful, non-essential, and unhelpful, 3) how professional development supports SCALE-UP instructors, and 4) how the classroom indirectly affects the department and/or institution. Based on their interviews, researchers found: 1) interviewees worked in teams to develop the SCALE-UP model and application to their individual institution. Often grants were required to help with any expenses of upgrading classrooms. 2) Collaborative workspaces, like shared tables, and other implements that enabled group work were helpful. Reviews were more mixed on high-tech advancements, in favor of anything that enabled more communication and participation. 3) Continuous training and support were required for teachers new (and continuing with) the SCALE-UP model. 4) the model had the indirect benefit of attracting visitors and instilling a reputation for high-quality education. [387]

Publication type: Journal article
Study type: research study
Sample: 21 faculty
Duration: Single point in time
Age or developmental stage: University faculty

le Roux, I., & Nagel, L. (2018). Seeking the best blend for deep learning in a flipped classroom – viewing student perceptions through the Community of Inquiry lens. *International Journal of Educational Technology in Higher Education*, 15(1). https://doi.org/10.1186/s41239-018-0098-x

In this paper, the researchers aim to study the effectiveness of the flipped classroom through the lens of Community of Inquiry (CoI) - a framework which organizes student learning in three main "Presences": Social, Teaching, and Cognition, as well as a few sub-categories (i.e. Learning, Emotional, and others). The researchers describe an in-depth case study of two third-year undergraduate courses on business/entrepreneurship for one semester at a large university in South Africa. The researchers used quantitative and qualitative data from students and teachers, including online data metrics, observation, interviews, and others. The researchers found that the individual online learning space (i.e., watching videos outside of the classroom) yielded strong Teaching Presence and Agency Presence, while in-class collaboration fostered deep learning of theory and boosted Cognitive Presence. Interestingly, the researchers noted that Social Presence was the weakest in the flipped classroom, surprising given that the flipped classroom emphasizes group work and active learning [382]

Publication type: Journal article
Study type: Case study
Sample: 2 classes
Duration: one semester
Age or developmental stage: University

Long, T., Logan, J., Cummins, J., & Waugh, M. (2016). Students' and Instructor's Attitudes and Receptions of the Viability of Using A Flipped Classroom Instructional Model In A Technology-Enabled Active Learning (TEAL) Classroom. *Journal of Teaching and Learning with Technology*, 5(1), 46–58. https://doi.org/10.14434/jotlt.v5n1.18879

The authors seek to obtain and analyze student and instructor perceptions of a classroom that fuses the flipped classroom framework with Technology Enabled Active Learning (TEAL) classrooms. These two frameworks have been implemented individually, but this study specifically highlights the overlap between the two. The researchers conducted in-depth interviews with five students and their instructor on their flipped-TEAL classroom environment. Overall, the Flipped-TEAL framework was well-received by students and the instructor. Students commented that they were engaged with the out-of-class videos, that the pre-class quizzes were useful for making sure they were prepared for class, and that in-class collaboration and group work fostered critical thinking and communication skills. There were some drawbacks - some students still did not show up prepared; some group work led to conflict; the abundance of technology was mostly good but could lead to distractions or difficulty understanding how to work the technology. [389]

Publication type: Journal article
Study type: Research Study
Sample: 5 students, 1 professor
Duration: Single point in time
Age or developmental stage: University students

Long, T., Logan, J., & Waugh, M. (2016). Students' Perceptions of the Value of Using Videos as a Pre-class Learning Experience in the Flipped Classroom. *TechTrends,* 60(3), 245–252. https://doi.org/10.1007/s11528-016-0045-4

In this article, the authors seek to learn about student perceptions of the flipped classroom, in particular the pre-class videos and written content used to learn the material before class. The researchers conducted a survey of students in one class at a Southeastern US university. The survey included both quantitative data (i.e. Likert scale questions) and qualitative data (open-ended opinion questions). They found 4 primary findings: 1) students primarily had positive feelings toward the pre-class videos and other content, 2) preferences varied as to the type of pre-class content, with instructor-developed videos scoring the highest, although text content was still valued, 3) students suggested that videos be kept short, recorded, and easily accessible so as to evade technical issues, 4) there was no statistically significant difference in the scores given by students across grade level, area of study, or previous experience of video learning [390.]

Publication type: Journal article

Study type: Research Study
Sample: 51 students
Duration: Single point in time
Age or developmental stage: University students

Long, T., Cummins, J., & Waugh, M. (2017). Use of the flipped classroom instructional model in higher education: instructors' perspectives. *Journal of Computing in Higher Education*, 29(2), 179–200. https://doi.org/10.1007/s12528-016-9119-8

In this article, the researchers seek to obtain the instructors' perspective on the flipped classroom model. In flipped classrooms students learn the material on their own before coming to class, and then class time is spent on active learning strategies, including group work and more project-based learning. The researchers performed in-depth interviews with eight teachers at various schools who had trained at Summer Teaching Institute, who had used or planned to use the flipped classroom model. The interviews were used to shed light on teachers' perceptions of this relatively new/innovating teaching model, and to gain their feedback on improving this more active style of learning. In general, teachers found active learning to be beneficial, both for students and for themselves. Learning the material at home and doing "homework" in class enabled teachers to provide direct and immediate support when questions arose, and increased communication/connection between students and teachers. One large difficulty was making sure students did the assigned reading and came to class prepared, and it was important for instructors to be organized in their active learning classrooms. [388]

Publication type: Journal article
Study type: Research Study
Sample: 8 teachers
Duration: Single point in time
Age or developmental stage: Teachers

McGregor, J. (2003). Making Spaces: Teacher workplace topologies. *Pedagogy, Culture and Society*, 11(3), 353–377. https://doi.org/10.1080/14681360300200179

McGregor addresses how the workplace environment is more than just the physical spaces and boundaries are given to teachers. The focus was on the social relations and what worked for interesting the built and non-built world at school. The methods involved in this research article were two secondary schools from an empirical study in England. The study measured the isolated classroom and the individual school combined with the local context and how the non-built workplace affected teachers. The study also measured the intersecting networks of relations that go beyond what is physically built at the schools. The study mapped and documented the physical space of the schools. The study also measured seating place, document collection, and photography of the spaces. The research article found that the study found space-time can be constantly remade and then produced and performed to understand social practices. This leads to the ability to understand the topologies o the workplace at schools. [407]

Publication type: Journal article
Study type: Research Article
Sample: 1 Empirical Study
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Secondary

Ovbiagbonhia, A. R., Kollöffel, B., & Den Brok, P. (2020). Teaching for innovation competence in higher education Built Environment engineering classrooms: teachers' beliefs and perceptions of the learning environment. European Journal of Engineering Education, 45(6), 917–936. https://doi.org/10.1080/03043797.2020.1784097

Ovbiagbonhia, Kollöffel, and Den Brok address how teachers are affected by the built environment where they are meant to teach and help students learn. Specifically, creative abilities to cope with difficult situations. The methods involved in the research study were 94 teachers who were given a questionnaire and they were measured on self-efficacy and the relationship with the learning environment. The study was measuring the perceived ability of teachers to support innovation competence. The study addressed the results with a multiple regression analysis. The study measured the perceptions of the learning environment, the focus of teachers on innovation competencies, reliefs relating to innovation competence teaching, and beliefs of the creative self-efficacy of teachers. The research study found that the beliefs that teachers had on creative self-efficacy could significantly predict what their perception was on personal relevance. The study also found that there was a perceived uncertainty around innovation competence. The study found that self-efficacy and the perception of teachers could predict student-student and teacher-student negotiations.[408]

Publication type: Journal article
Study type: Research Article
Sample: 94 Teachers
Duration: Single Point in Time, Cross-sectional
Age or developmental stage: Higher Education

Palak, D. (2004). Design Strategies for Higher Education Faculty. *The Turkish Online Journal of Educational Technology-TOJET*, 3(2), 1303–6521. https://search.proquest.com/docview/1288368453/1B264D3B328E4E66PQ/16?accountid=166860

In this paper, the author conducted a thorough review of literature relevant to the concepts and frameworks relating to the design of higher education facilities, as well as the impact on student-centered learning pedagogies. There are five main strategies that are considered: 1) the scope of change in design strategies as a result of current school reform in the United States, 2) impact of instructional technologies on teaching and learning, 3) evolving roles of teachers and learners within these new environments, 4) new networked technologies available for teaching, and 5) implications for changes in instructional strategies. The author highlights several relevant studies and other research papers that relate to these strategies. One of the main takeaways from the literature review is the concept of learner-centric pedagogies, and learners having more agency and control over their own learning. A major point in the paper is the shifting roles of teachers and learners, giving learners more control, and teachers transitioning from an

authoritative figure to a more collaborative figure. [402]

Publication type: Journal article
Study type: Literature review
Age or developmental stage: University

Raffaghelli, J. E. (2017). *Does Flipped Classroom work? Critical analysis of empirical evidences on its effectiveness for learning.* 17(3), 116–134. http://www.fupress.com/formarearticoli

This paper presents a literature review of 17 research articles on the Flipped Classroom (FCM) in order to ascertain the effectiveness of the flipped classroom on student learning and performance. The selected research studies varied in their age of student studied, scope of the research, and focus. The author concluded that FCM shows promise, and evidence indicates that FCM likely contributes to improved student motivation and performance. However, she is careful to note that many of the most focused and thorough research articles were cautious in their positive reviews of FCM, noting that it is difficult to establish that it is the flipped classroom specifically that results in positive outcomes. She also found that a small number of the 17 articles were critical of FCM. The review concluded that more research is needed to get closer to verifying the claim that FCM leads to improved performance. The author proposes three realms of future study/focus for FCM: methodology, pedagogy, and organizational structure.[392]

Publication type: Journal article
Study type: Literature review
Sample: 17 studies

Rudd, J. R., O'Callaghan, L., & Williams, J. (2019). Physical education pedagogies built upon theories of movement learning: How can environmental constraints be manipulated to improve children's executive function and self-regulation skills? International Journal of Environmental Research and Public Health, 16(9). https://doi.org/10.3390/ijerph16091630

Rudd, O'Callaghan, and Williams address how physical education in primary schools is affected by the built environment. Specifically, the improvement of the built environment to improve the executive function and self-regulation skills of children. The methods involved in this research paper were articles that addressed physical education for primary students affects motor learning. The measurements were on the ability of the studies to describe supporting teachers when creating learning environments and guiding teachers with their pedagogical practices to allow for the development of cognitive skills for children. The paper focused on the executive function and self-regulation skills of children and how to improve them with physical education starting at an early age. The paper found that physical education can lead to higher academic performance and cognitive performance. The study also found that teaching children about physical education are crucial for the development and learning abilities of children. Self-regulation skills and executive function were found to be predictors of academic achievement, even more than IQ. [409]

Publication type: Journal article

Study type: Research Paper
Sample: NA
Duration: Cross-sectional
Age or developmental stage: Primary

Safapour, E., Kermanshachi, S., & Taneja, P. (2019). A review of nontraditional teaching methods: Flipped classroom, gamification, case study, self-learning, and social media. *Education Sciences*, 9(4). https://doi.org/10.3390/educsci9040273

This paper presents a literature review of of five of the most prominent non-traditional classroom teaching methods: flipped classroom, gamigication, case studies, self-learning, and social media. The goal was to codify the benefits associated with each method, so that teachers and researchers of education may better be able to understand and compare the methods, which may also spill over into the design of classrooms. Out of over 2000 research studies published since the year 2000 on these nontraditional approaches, the researchers identified 125 recent and relevant articles. They highlighted the methods used in these articles, which ranged from quantitative performance data (like student test scores) to more qualitative and open-ended data, like surveys/questionnaires. The researchers found numerous but varied benefits to each of the five nontraditional methods. Not only did the benefits differ between the five, but they also differed depending on the "audience", i.e. middle school-aged children vs graduate students in an engineering program. The summarized list of benefits may be used for teachers deciding how best to implement their pedagogy in a classroom, as well as designers hoping to create flexible and adaptable spaces. [393]

Publication type: Journal article
Study type: Literature review
Sample: 125 studies

Tan, L. S., Lee, S. S., Ponnusamy, L. D., Koh, E. R., & Tan, K. C. K. (2016). Fostering creativity in the classroom for high ability students: Context does matter. *Education Sciences*, 6(4). https://doi.org/10.3390/educsci6040036

This paper explores how different classroom contexts foster creativity. This study measured creativity using the e Wallach-Kogan Creative Thinking Test (WKCT) on 283 students of the Express Program (EP) and 290 students of the Integrated Program (IP). The same students took the test twice at different stages of their secondary studies. The study looked at four aspects of creativity: fluency, flexibility, unusualness, and uniqueness, and found that IP students showed greatest increase over time, compared to EP students, and that flexibility scores were more difficult to change than fluency scores. The authors conclude that classroom context is important, and that the removal of high stakes exams can promote creativity. [383]

Publication type: Journal article
Study type: Research Study
Sample: 573 students
Duration: Longitudinal, tests at different points of secondary studies
Age or developmental stage: Secondary students

Whitehouse, D. (2009). Designing learning spaces that work: a case for the importance of history. *History of Education Review*, 38(2), 94–108. https://doi.org/10.1108/08198691200900016

The authors conducted a review and analysis of historical accounting and photographs of a few of the 20th century's Modernist schools, built by Neutra, the Saarinens, and others. They aimed to glean strategies in the designs that would inform an overarching theme to innovative school design. The authors used historical texts and, primarily, photographs of Neutra's Corona Ave elementary school, the Saarinen's Crow Island school, among others, to study their innovative techniques to design nontraditional schools. In the conclusion, the authors note the strategies that were used by these influential architects and suggest inspiration for today's designers as they create innovative schools in the 21st century. Most notably, the authors state, "While individually distinctive, these schools' interior design is characterized by a holistic concern with developmental stages, child proportions and details, flexible, lightweight, child scale furniture for different modes of work, diverse and purposeful settings, spatial transparency, and the integration of the latest technologies, tools and materials with the organic as in natural light and inside and outside settings." [394]

Publication type: Journal article
Study type: Historical research

Winter, J. W. (2018). Performance and Motivation in a Middle School Flipped Learning Course. *TechTrends*, 62(2), 176–183. https://doi.org/10.1007/s11528-017-0228-7

This paper aimed to identify a relationship between student motivation and performance in a flipped classroom framework. The author used as a case study a 6th grade social studies class at a private middle school in Hawaii. Over an 8-week period, with students who had never participated in a flipped classroom, the author measured student performance data and conducted a qualitative survey that included some open-ended questions as well as Likert-scale questions. The study found that the technology-based content involved in a flipped classroom may lead to increased motivation and improved performance. The author noted that this appears to be true not only for high-performing students, but for more average students as well through differentiated instruction. He noted that the findings suggest that classrooms should be designed to maximize student engagement and incorporate learner-appropriate strategies. [391]

Publication type: Journal article
Study type: Case study
Sample: 35 students
Duration: 8 weeks
Age or developmental stage: sixth grade (11 to 12 years old)

van Merriënboer, J. J. G., McKenney, S., Cullinan, D., & Heuer, J. (2017). Aligning pedagogy with physical learning spaces. European Journal of Education, 52(3), 253–267. https://doi.org/10.1111/ejed.12225

Van Merriënboer, McKenney, Cullinan, and Heuer address how physical

spaces in schools and school buildings affect pedagogy and learning. Specifically, how spaces can help to support learning and pedagogy. The methods involved in this research article were a participatory design process and three phases surrounding the purpose. The first phase was being specific about what the pedagogy is and this involved measuring different ways educators provide materials and teach students. The second phase was matching the physical learning spaces with the seating arrangement of students to allow for the connection to the pedagogy. The third phase was creating the school building. The article found that it is important to understand what pedagogy is and determine its factors in learning spaces. The article found that it is important to understand how important the first and second phases are in addressing pedagogy. The design process was found to need to address interior designs and architects and their ability to collaborate with teachers, students, and school management. [410]

Publication type: Journal article
Study type: Research Paper
Sample: 2 Schools
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Primary and Secondary

Zandvliet, D., & Broekhuizen, A. (2017). Spaces for learning: development and validation of the School Physical and Campus Environment Survey. *Learning Environments Research*, 20(2), 175–187. https://doi.org/10.1007/s10984-017-9228-y

The authors aimed to test the validity of a new type of survey/questionnaire they call SPACES: School, Physical, and Campus Environmental Survey, by implementing this survey and supplementing it with other forms of research, including behavior observation and focus groups. The authors selected a newly built high school in a community in which the old high school had recently been razed and built anew. In the first year of operation at the new school, researchers conducted the SPACES questionnaire, observation, informal interviews, and focus groups. The research served as somewhat of a POE, as well as a means to learn what worked and what didn't specifically with regards to the impact of the physical environment on learning. The researchers found that the validity of the SPACES questionnaire was verified, by comparing the results of the survey to interviews and focus groups with students and staff, as well as qualitative discussions of student drawings of a traditional classroom vs an informal learning environment. The new school got high marks in many areas - lighting, flexibility, comfort, and more, but actually scored fairly low on ambience (air quality) - which led to upgrades in the school's ventilation system. [396]

Publication type: Journal article
Study type: Research Study

Participatory Design

Ahmadi, R., & Saiki, D. (2017). Strategies To Assess Studio Spaces Designed To Enhance Student Learning. 109(1), 57–62.

In this article, the authors' intention was twofold. First, they wanted to identify helpful architectural strategies in a studio learning environment. Second, they aimed to highlight three useful methods for including students in the design process in a more general setting to learn what design strategies would be most appropriate for a different learning environment. They identified a Family and Consumer Science class at Ball State University and conducted a full-day participatory charrette, as well as behavior observation and focus groups with students. The researchers identified five strategies from the three research methods: 1) Creation of collaborative areas (results from charrette and focus group), 2) Purchase of more flexible furniture to accommodate a variety of activities, 3) Creation of spaces to display students' work, 4) Incorporation of accent wall for visual interest, 5) Elimination of congested areas by the entrance [418].

Publication type: Journal article
Study type: Research Study

Clement, J. (2019). Spatially Democratic Pedagogy: Children's Design and Co-Creation of Classroom Space. *International Journal of Early Childhood,* 51(3), 373–387. https://doi.org/10.1007/s13158-019-00253-4

The author conducts a case study of children's participation in the design process of a classroom, as part of a wider framework called Spatially Democratic Pedagogy. The author seeks to observe and analyze the effects of young children having a participatory role in the design of their classroom space. The research was conducted with six young children (ages 4-5) and their teacher in South Wales. There were seven stages to the process: 1) Empty the space, 2) Initial designs, 3) Group designs, 4) Materials needed, 5) Create materials, 6) Create the space, 7) Use the space. Throughout the process, interviews and observational tactics were used to gauge student involvement and participation. They found that overall, Spatially Democratic Pedagogy has many benefits, especially when used by younger children, since these are critical years of social and educational development. The student becomes teacher, architect, problem-solver, and negotiator. In addition to creating a space that is conducive to learning, the process of participation brings students closer to each other and to their teachers, as well as instills a sense of pride and ownership in the space. The authors argued that the participation process should go beyond just planning and include actual construction as well, within the limits of safety and practicality. [415].

Publication type: Journal article
Study type: Research study
Sample: 6 children
Duration: 7 stages
Age or developmental stage: 4 to 5 years old

Cober, R., Tan, E., Slotta, J., So, H. J., & Könings, K. D. (2015). Teachers as participatory designers: two case studies with technology-enhanced learning environments. *Instructional Science,* 43(2), 203–228. https://doi.org/10.1007/s11251-014-9339-0

The researchers use two case study schools - a sixth grade class in Ontario, Canada, and a secondary school in Singapore - to highlight the importance of teacher participation in the design process. The researchers teamed up with teachers at the two schools in the design and implementation of both the designed environment and the pedagogy/curriculum at the two schools and used observational and interview research to distill their research. Two teachers in Canada suggested new design features, introduced pedagogical requirements, and provided feedback on design ideas. It was essential that teachers felt listened to and that their ideas were respected, and in that way felt more ownership in the process. In Singapore, six teachers theorized and bridged knowledge building principles, worked on pedagogical prototyping, and collaborated/evaluated technology integration. [417]

Publication type: Journal article
Study type: Case studies
Sample: 2 schools, 2 teachers (school 1), 6 teachers (school 2)
Duration: 2 moths per school, 90-minute meetings
Age or developmental stage: Teachers

Ghaziani, R. (2012). An Emerging Framework for School Design Based on Children's Voices. *Children, Youth and Environments*, 22(1), 125–144.

The author analyzes three previous studies of schools in England and the importance of user participation - but notes that the "users" involved typically only included teachers and other faculty, rather than students. The author then conducted a study to bridge the gap in make students' voices heard. The author conducted a questionnaire with 260 student participants at two schools (one old and one new) in the UK and compared answers to draw conclusions. To evaluate the schools, they look at indoor spaces, comfort and control, activity spaces, nature and outdoors, facilities (services), and exterior. The compiled findings revolved around physical safety, flexible spaces, access or views to the outdoors, comfortable spaces, and privacy. [411]

Publication type: Journal article
Study type: Research study
Sample: 260 surveys, 2 schools
Duration: Single point in time
Age or developmental stage: 11 and 12 years old

Gislason, N. (2010). Architectural design and the learning environment: A framework for school design research. *Learning Environments Research, 13(2*), 127–145. https://doi.org/10.1007/s10984-010-9071-x

This study analyzed high schools and the effect of ecology systems (design, structure, and environmental), organization, culture of staff, and culture of students on learning and development. First, the author conducted a literature review, and then underwent behavioral observation and interviews at the High School for Recording Arts (Minneapolis/St. Paul). This methodology

allowed the researcher to compare these research methods with the current literature. In the findings, school organization and the architectural qualities of the school mutually impacted each other and were both found to be influential on culture of the staff and students [416].

Publication type: Journal article
Study type: Case study, Theory development
Sample: 1 high school
Age or developmental stage: 9 to 12 years old

Hall, T. (2017). Architecting the "third teacher": Solid foundations for the participatory and principled design of schools and (built) learning environments. *European Journal of Education*, 52(3), 318–326. https://doi-org.libproxy.uoregon.edu/10.1111/ejed.12224

Hall addresses how the built environment and design of schools can act as a "third" teacher and it can also affect learning and school spaces. The methods involved in this issue are five texts that address architecture, construction, and educational policy. The issue also involved how the participatory design can be implemented into a school design and how success can be achieved. The five articles were written by authors connected to the built environment that had ideas and measured performance and design abilities. The issue also measured architecture stakeholders, design tools for professionals and non-professionals, how technology can help success, different models of design, and sensitives to designs. The issue found that schools need to consider their design sensitivities, space, engagement, aesthetics, and media when addressing the built environment at schools. The issue also found that a participatory design allowed for engagement and an increase in the abilities of students.[420]
Publication type: Journal Article
Study type: Issue, Literature Review
Sample: 5 Texts
Duration: Cross-sectional
Age or developmental stage: School Age

Ismail, A. S., & Zulkurnain, N. S. Z. (2019). The Role of Environment As Third Teacher Towards The Development Of Educational Space For Dyslexic Children. *International Journal of Built Environment and Sustainability*, 6(2), 51–62. https://doi.org/10.11113/ijbes.v6.n2.356

Ismail and Zulkurnain address how learning spaces impact students with dyslexia and how the design of spaces can act as a "third" teacher for students to increase their ability to learn. The methods involved in this paper were qualitative that involved a case study that addresses learning spaces for dyslexic children. The paper measured students by direct observations of three case studies that focused on learning disabilities. The paper measured the learning process and development of students with learning disabilities. The study also measured auditory, tactile, and visual cues and kinesthetic approaches. The paper also measured the density and size of spaces that were used for learning. The study found that builders, designers, educators, and authorities related to learning need to understand the impact the environment has on students and their ability to learn, specifically how it impacts dyslexic children and learning disabilities. The study also found that

public education infrastructure needs to be improved to support dyslexic students and their quality of learning. [421]

Publication type: Journal Article
Study type: Research Paper
Sample: 3 Studies
Duration: Cross-sectional
Age or developmental stage: Primary, 7 to 12 Years Old

Jenifer Marley, MaryEllen C. Nobe, Caroline M. Clevenger, & James H. Banning. (2015). Participatory Post-Occupancy Evaluation (PPOE): A Method to Include Students in Evaluating Health-Promoting Attributes of a Green School. *Children, Youth and Environments,* 25(1), 4. https://doi.org/10.7721/chilyoutenvi.25.1.0004

In this paper, the authors propose methods to develop POEs including views from the students. The authors first introduce a lit review on POE's in school design. Then, they discuss their process of conducting a Participatory Post-Occupancy Evaluation (PPOE) involving six 4th grade students at a LEED Gold Certified elementary school in Colorado and highlight the Photovoice method of POE which involves taking photos and discussion. The researchers met with students once a week for four weeks, with a different task each week. 1: Introduction and focus group; 2: Taking the photographs, 3: Participatory data analysis (selecting, contextualizing, and coding the photos), 4: Presentation of results. These were the 14 factors that emerged as most important from the POE: circulation, community connectivity, connection to nature, spaces to express creativity, equipment for cleanliness, equipment for conservation, exposed systems, learning spaces, lighting, materials, physical activity and play, signage and informational artifacts, technology, and water sources. The authors conclude by highlighting the significance of whole human health, as in not just bodily health but also social, cultural, and how these are affected by the school environment. [414]

Publication type: Journal article
Study type: Research Study
Sample: 6
Duration: one month
Age or developmental stage: 4th grade

Killeen, J. P., Evans, G. W., & Danko, S. (2003). The role of permanent student artwork in students' sense of ownership in an elementary school. *Environment and Behavior*, 35(2), 250–263. https://doi.org/10.1177/0013916502250133

Killeen, Evans, and Danko address how permanent art created by students affects students' sense of ownership. Specifically, how the design of the built environment can influence the beliefs of students about the space they learn in. The methods involved in this case study were 377 students that were in fourth and fifth grade and were a part of an experimental study that addresses the sense of ownership. The experimental study measured artwork and the feelings of students with questionnaires. The artwork was determined due to the type of lessons that teachers taught to students, which allowed connection to the student and the artwork to be formed and then tested. The study found that there was an association that was significant between

students' sense of ownership and school design. The study also found that there were stronger student perceptions and a stronger sense of ownership when their artwork was displayed permanently. [422]

Publication type: Journal Article
Study type: Research Study
Sample: 377 Student
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Elementary

Könings, K. D., & McKenney, S. (2017). Participatory design of (built) learning environments. In *European Journal of Education* (Vol. 52, Issue 3, pp. 247–252). Blackwell Publishing Ltd. https://doi.org/10.1111/ejed.12232

Könings and McKenney address how the built learning environment is affected by its ability to allow for participation. Specifically, designs and policies that could be implemented to create a participatory learning space. The methods involved in this editorial were 5 articles that address participatory designs and perceptions of teachers, students, architects, educators, adults, student performance, and relationship connections between them all. The editorial measured how issues related to each other and possible ways that students and teachers address the built environment. The editorial also analyzed technology, socioeconomic status, cultural background, student performance, and beliefs of different groups. The editorial found that there needs to be a change in the requirements for participatory infrastructure. Teachers and designers need to find relationships between spaces and what is being taught to create a space that allows for participation. The editorial also showed how important a participatory design was and what tools and concepts can be considered.[423]

Publication type: Journal Article
Study type: Editorial, Literature Review
Sample: 5 articles
Duration: Cross-sectional
Age or developmental stage: Teachers, Students, University

Mäkelä, T., Helfenstein, S., Lerkkanen, M. K., & Poikkeus, A. M. (2018). Student participation in learning environment improvement: analysis of a co-design project in a Finnish upper secondary school. *Learning Environments Research*, 21(1), 19–41. https://doi.org/10.1007/s10984-017-9242-0

The authors researched the role and impact of student participation in a redesign of their learning environment. Their goal was to analyze student perceptions to being included, whether their insight was implemented, the impacts of their suggested redesigns, and the impact that participation in the process had on their feelings of ownership and inclusion. The authors identified students at a secondary school in Finland for their study. They conducted mixed-method, qualitative experiment, including interviews, focus groups, and surveys during and after the design process and implementation. Generally, the students felt that their design wishes were incorporated, including renovations focusing on communality, individuality, comfort & health, and novelty & conventionality. Students also felt perceived

improvements due to these renovations, and student involvement also prevented overly radical changes from taking place. Student involvement also fostered a participatory culture and feelings of inclusion/ownership, and contributed to understanding what students view as important to their learning and well-being. [419]

Publication type: Journal article,
Study type: Case study
Sample: co-design activities (n = 11), student feedback (n = 175), professional design evaluation (n = 2), satisfaction survey (n = 83)
Duration: Single point in time
Age or developmental stage: Upper secondary school

Manahasa, O., Özsoy, A., & Manahasa, E. (2021). Evaluative, inclusive, participatory: Developing a new language with children for school building design. *Building and Environment,* 188(September 2020). https://doi.org/10.1016/j.buildenv.2020.107374

To study and promote the idea of student participation in design/redesign of school spaces, including via participatory post-occupancy evaluations. The study included 502 children aged 10-14 at three schools in Albania. The research utilized a variety of qualitative methods, both creative and evaluative, to include student participation: essays, wish poems, drawings, model making, poster design, questionnaires, and walk-throughs were included. The researchers identified six primary goals of school design as an outcome of the study: flexibility, horizontality, campus-like environment, transparency, accessibility, and ecological concept. [412]

Publication type: Journal article
Study type: Research study
Sample: 502 students
Duration: 5 workshops
Age or developmental stage: 10 to 14 years old

Taylor, A. (2013). The Learning Environment as a Three-Dimensional Textbook Author (s): Anne Taylor Source : *Children's Environments* , Vol . 10 , No . 2 , School Design : A Continuous Process Published by : The Board of Regents of the University of Colorado, a body cor. 10(2), 170–179.

The author (along with research partner architect George Vlastos) use two schools - in Trout Lake, WA and Stockton, CA - as case studies of student participation in the design process of schools. The author makes the case that schools should not be passive, empty vessels in which learning takes place, but should be active stimuli in the process of learning - and the best way to achieve this is through student participation in design. The author highlights the process of user participation in the two case study schools, and areas where the resulting building was successful for the students. Based on the successes of the two case studies, the author presents various frameworks or patterns/principles for architects to consider in school design, based on these case studies. [413]

Publication type: Journal article
Study type: Case study

Sample: 2 case studies
Age or developmental stage: 5 -12 years old.

Woolner, P., Hall, E., Wall, K., & Dennison, D. (2007). Getting together to improve the school environment: User consultation, participatory design and student voice. *Improving Schools*, 10(3), 233–248. https://doi.org/10.1177/1365480207077846

Woolner, Hall, Wall, and Dennison address how to create a school environment that has a participatory design based on student voice and user consultation. The methods involved in this case study is a high school for boys in Aibirth, Liverpool and 992 students attend the school with ages ranging from 11 to 18 years old. The methods involve a project called the Schools Renaissance that addresses how students see their school and allow them to have the main role in the design process of a school. The study measured teachers' perspectives and students' perspectives on a new learning space. The case study found that consulting students about a school design allow for a participatory lesson and the ability to focus on creating a school that is inclusive for the student's learning. The study also found that frustrations may occur during the process, but the ability to listen to all voices needs to occur. [424]

Publication type: Journal Article
Study type: Case Study
Sample: 992 Students, 1 School
Duration: Cross-sectional, Longitudinal, 1 School Year
Age or developmental stage: High School

Universal Design for Learning Special Education

Brunzell, T., Stokes, H., & Waters, L. (2016). Trauma-Informed Flexible Learning: Classrooms That Strengthen Regulatory Abilities. *International Journal of Child, Youth and Family Studies*, 7(2), 218. https://doi.org/10.18357/ijcyfs72201615719

The authors' aim to study flexible learning spaces as they pertain to students with past trauma and require intentional pedagogical approaches to learn in a healthy setting that cares for their mental well-being (in ways that students without a past history of trauma may not). They study this through the Trauma-Informed Positive Education (TIPE) framework. After conducting a literature review, the researchers detailed a qualitative case study which embedded the researchers within a classroom working with the TIPE framework at an Australian school with students aged 12-17. The research consisted of observation and group interviews with teachers. The researchers specify that this study looks at the first of three domains of TIPE, which is referred to as "increasing regulatory abilities" and is part of a larger study that considers all three domains. They discuss four sub-categories of

this first domain: rhythm, self-regulation, mindfulness, de-escalation. There are specific actions and activities within the flexible learning classroom that pertain to each of these sub-categories [430].

Publication type: Journal article
Study type: Case study
Sample: 9 teachers
Duration: Longitudinal, 13 weeks (first phase)
Age or developmental stage: Teachers in a school for 12 to 17 years old

Ehlinger, E., & Ropers, R. (2020). "It's All About Learning as a Community": Facilitating the Learning of Students With Disabilities in Higher Education Classrooms. *Journal of College Student Development*, 61(3), 333–349. https://doi.org/10.1353/csd.2020.0031

This paper aims to identify factors that facilitate learning and barriers to learning for students with disabilities. Disabilities can refer to physical or cognitive disabilities or mental illness. The factors of study involved physical school environments as well as attitudes or perceptions of teachers and fellow classmates. The researchers discuss a qualitative case study research with 13 students with disabilities at a large Midwestern US university. The research involved two rounds of interviews (at the beginning and end of a semester) as well as four separate rounds of journal entries by the students. As a result of the qualitative research, the researchers divided the results into elements/practices that facilitated learning and feelings of acceptance/belonging, and barriers to learning/acceptance. Facilitators included 1) Instructor messaging, 2) Community in the classroom, and 3) Validating identity and bringing in diverse perspectives. Barriers included 1) Instructor role (mostly unintended comments or actions that revealed systemic discrimination), 2) Classroom dynamics, 3) Oppression, ableism, and stigma. [431]

Publication type: Journal article
Study type: Research study
Sample: 13 college students
Duration: Single point in time
Age or developmental stage: University

Lopes-Murphy, S. (2012). Universal Design for Learning: Preparing Secondary Education Teachers in Training to Increase Academic Accessibility of High School English Learners. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 85(6), 226–230. https://doi.org/10.1080/00098655.2012.693549

In this review the author seks to highlight the use of Universal Design in Learning (UDL) for students who are English Learners, and could benefit from thoughtful planning and design. The author conducts a thorough review of relevant literature to make recommendations. Some design ideas that would fit the UDL framework include: instructional tools and strategies that are flexible and engaging and that allow learners to demonstrate learning in multiple ways; presentation approaches that, in addition to verbal and written, rely on resources that are appealing to different learning styles; alternative ways through which learners can demonstrate their knowledge; a variety of scaffolding devices that incorporate charts and graphic organizers while material is presented; visuals that supplement printed materials; classroom

configurations that allow for small-group work and collaboration; a variety of instructional methods that stimulate student engagement and motivation; the involvement of students through meaningful participation in learning activities [425]

Publication type: Journal article
Study type: Literature review

Martin, C. S. (2016). Exploring the impact of the design of the physical classroom environment on young children with autism spectrum disorder (ASD). *Journal of Research in Special Educational Needs*, 16(4), 280–298. https://doi.org/10.1111/1471-3802.12092

Martin addresses how children with autism spectrum disorder (ASD) are impacted by their classroom design. The methods involved in this study were 19 articles and 1 conference proceeding that address how children with ASD can be supported in their physical classroom environment. The factors that were measured in the classrooms were human factors, lighting, acoustics, indoor air quality, and thermal comfort. Post-occupancy evaluation, research, theories, and universal design were also factors that were measured. The review and study measured similarities and differences in studies that showed a variety of results. The study and literature found that there should be a heuristic approach when designing a classroom environment for children with ASH. The study and review found that decisions need to be made from evidence-based strategies. The study also found that there is a limit in the sample sizes, so it is important to understand that results will vary between spaces. [432]

Publication type: Journal Article
Study type: Research Study/Literature Review
Sample: 19 Articles, 1 Conference Proceeding
Duration: Cross-sectional, Longitudinal, 12 Years
Age or developmental stage: Young Children

Meo, G. (2008). Curriculum Planning for All Learners: Applying Universal Design for Learning (UDL) to a High School Reading Comprehension Program. *Preventing School Failure: Alternative Education for Children and Youth,* 52(2), 21–30. https://doi.org/10.3200/psfl.52.2.21-30

In this paper the author introduces the concept of Universal Design for Learning (UDL), and discusses a case study of a high school social studies class that implemented a UDL curriculum. The goal is to highlight the advantages of implementing UDL into an educational pedagogy in order to engage a wide range of learners, with different learning styles. After discussing the background research into UDL, the author discusses two high school teachers - a special education teacher and a teacher of typical classes - and their training and implementation of UDL in their classes. Together with a team of UDL professionals, called the Planning for All Learners (PAL) team, a series of focus groups and trainings took place to prepare the teachers to adapt their curriculum. Through focus groups with the PAL team, four steps in the UDL process took shape: 1) Set goals, 2) Analyze current status of curriculum and classroom, 3) Apply UDL to lesson or unit development, 4) Teach the UDL lesson or unit. The non-special education teacher in the study

remarked that before, he had considered student failure a personal problem, and their fault - rather than a failure of the curriculum or other barrier to learning. [427]

Publication type: Journal article
Study type: Case Study
Sample: 2 teachers
Duration: Single point in time
Age or developmental stage: High school

Spooner, F., Baker, J. N., Harris, A. A., Ahlgrim-Delzell, L., & Browder, D. M. (2007). Effects of training in universal design for learning on lesson plan development. *Remedial and Special Education*, 28(2), 108–116. https://doi.org/10.1177/07419325070280020101

The authors sought to determine how a brief training on UDL (Universal Design in Learning) might impact teaching students' lesson plans. The researchers identified 72 undergraduate and graduate students in an education program at a southeastern US university as the research participants. Participants were randomly assigned to the experimental group or the control group. The experimental group received 1-hr of specific UDL training before an assignment to design an elementary school lesson plan; the control group received the training after the assignment. Lesson plans were scored based on accessibility for students with various disabilities and impairments, in order to determine how impactful a 1-hr training on UDL might be in student learning. The researchers instituted a scoring system which "graded" lesson plans based on three tenets of UDL: representation, expression, and engagement. The experimental group, crafted lesson plans which were more suitably and appropriately accessible to all types of students. [426]

Publication type: Journal article
Study type: Experimental study
Sample: 2 groups of students
Duration: Single point in time
Age or developmental stage: University students

Staats, S., & Laster, L. A. (2018). Extending universal design for learning through concurrent enrollment: Algebra teachers' perspectives. *Education Sciences,* 8(4). https://doi.org/10.3390/educsci8040154

The researchers aim to make the case for the concept of concurrent enrollment (where students take that are valid for university credit at their secondary institution), as an opportunity for Universal Design for Learning (UDL) to tackle issues of race, socioeconomic class, and other potential systemic barriers. They conducted several semi-structured focus groups with high school and college teachers in Minnesota that participated in a concurrent enrollment program, and specifically focused on the equity goals of the program. As a result of the research, the authors found that "teachers 1) describe equity in social terms of race, ethnicity, income, immigration, and language status in addition to measures of academic success; 2) perceive improvements in students' attitudes towards mathematics, school, and university education; 3) perceive student academic growth through

mathematical writing; and 4) report close relationships with students." [428]

Publication type: Journal article Dissertation
Study type: Research Study
Sample: 27 teachers
Duration: Single point in time
Age or developmental stage: secondary teachers

Summers, T., & Beers, M. (2019). Ready for Equity? A Cross-Cultural Organizational Framework to Scale Access to Learning-Ready Classrooms That Support Student Success. *Journal of Teaching and Learning with Technology*, 8(1), 76–86. https://doi.org/10.14434/jotlt.v8i1.26889

In this paper, the authors aim to make the case that, rather than focusing on a small number of technology and resource-intensive active learning classes, educators and administrators should focus on universal access to "learning-ready classrooms" by focusing on universal design and accessibility across race, class, gender, ability, socioeconomic status, etc. The authors review relevant literature and evaluate a case study example of learning-ready universal design classrooms as part of the Classroom Readiness Committee (CRC) at San Francisco State University. The authors use existing literature and the case study example to make the argument that universally designed, learner-ready classrooms can be more widely offered and would be available to everyone, which competes with the notion that only privileged students would have access to technologically advanced learning classrooms. The 8 universal design goals are specified as: 1) Body fit, 2) Comfort, 3) Awareness, 4) Understanding, 5) Wellness, 6) Social Integration, 7) Personalization, and 8) Cultural appropriateness. [429]

Publication type: Journal article
Study type: Case study, theory development
Age or developmental stage: University Students

People / socialization - In between spaces

Doshi, A., Kumar, S., & Whitmer, S. (2014). Does Space Matter? Assessing the Undergraduate "Lived Experience" to Enhance Learning. *Planning for Higher Education Journal*, V43N1(December), 1–21. https://smartech.gatech.edu/handle/1853/52648

The authors used a literature review and a case study to determine spatial attributes of a campus commons to best serve the students' learning and well-being. After conducting a review of relevant literature, the authors describe their case study research of Clough Commons, an undergraduate commons building at Georgia Tech in Atlanta. The Commons serve undergrads with study areas, academic advising, food options, and more. The researchers used a mixed methods approach, including behavior observation, ethnographic

research, interviews, and more. They summarized their data by identifying 11 different "use modes" of student activity. For example, "meet up" to describe students using the Commons as a meeting point in the center of campus, and "grab n go" to describe students who came to the Commons for a specific purpose, performed the activity, and then left. They also use the data to make recommendations for campus planners working on university commons, described in the next section. [436]

Publication type: Journal article
Study type: Case Study
Sample: One university commons
Duration: One semester
Age or developmental stage: University

Epstein, J. L., & Sheldon, S. B. (2002). Present and accounted for: Improving student attendance through family and community involvement. *Journal of Educational Research*, 95(5), 308–318. https://doi.org/10.1080/00220670209596604

Epstein and Sheldon address how community and family involvement affects student attendance and could potentially help increase attendance. The methods involved in this study were 12 elementary schools and 6 secondary schools that were given a baseline, midyear, and final survey during the years 1996-1997. Surveys asked schools about goals for attendance, attendance rates, and community and family practices in terms of involvement. The attendance rates were from 3 school years in a row at each school. The study found that there was a prediction of an increase in daily attendance when there were partnerships between the school, community, and family. The study also found that when there was a partnership between the school, family, and community there was also a decrease in chronic absences for students. The study also found there if more activities combined the family and community with the school, there may be a potential to increase student attendance at elementary schools. [438]

Publication type: Journal article
Study type: Longitudinal Study
Sample: 18 schools
Duration: Longitudinal, 1-3 Years
Age or developmental stage: Elementary and Secondary

Gislason, N. (2009). Mapping school design: A qualitative study of the relations among facilities design, curriculum delivery, and school climate. *Journal of Environmental Education*, 40(4), 17–34. https://doi.org/10.3200/JOEE.40.4.17-34

The author aims to draw a connection between the school's architectural layout, student participation and performance, and social/cultural connections among students and faculty. The author conducted a three-week case study at a School of Environmental Studies (SES), a senior public high school in Minneapolis/St Paul with an environmental studies focus. During the study period, he conducted interviews and behavior observations that related to students' perceptions of the primarily open-plan spaces and communal/collaborative work environments. Students interviewed and observed were

positive in their reviews of the open-plan concept versus more traditional classroom settings, as this allowed more social connections, collaborative study, and to connect with more peers and teachers than otherwise possible. They felt more socially accepted and enjoyed being at school more. [435]

Publication type: Journal article
Study type: Case study
Duration: three weeks
Age or developmental stage: Grade 11 to 12

Hod, Y., & Katz, S. (2020). Fostering highly engaged knowledge building communities in socioemotional and sociocognitive hybrid learning spaces. *British Journal of Educational Technology*, 51(4), 1117–1135. https://doi-org.libproxy.uoregon.edu/10.1111/bjet.12910

Hod and Katz address how learning spaces create engaged communities and affect the socioemotional and sociocognitive values of students. The methods involved in this case study were 1,780 online notes collected from students over the course of a semester. The study measured conversations chains and how students interacted with each other. The notes were measured on their socioemotional or sociocognitive values and compared to each other. The study also focused on hybrid learning spaces that allow for the flow of information online and moderators helped lead 18 students throughout the study. The study also focused on the measurement of learning. The case study found that socioemotional values are affected by varying beliefs in topics and that although students may not agree on an uncomfortable topic, they may all agree that discussing the topic causes emotional turmoil. The case study also found that sociocognitive and socioemotional dimensions are connected to each other and both affect learning. [439]

Publication type: Journal article
Study type: Case Study
Sample: 18 students, 1,780 notes
Duration: Longitudinal, 1 Semester
Age or developmental stage: Graduate Students

Maina, J. J., & Ibrahim, R. H. (2019). Socialisation Mediates the Relationship Between Learning Environments and Architecture Students' Academic Performance. *International Journal of Built Environment and Sustainability*, 6(3), 43–52. https://doi.org/10.11113/ijbes.v6.n3.416

This paper investigates the relationship between learning environments (LE) and academic achievement from the perspective of architecture students. It examines a set of qualitative open-ended responses from 29 students majoring in architecture. The paper reported that while learning environments were generally conducive, they also positively influenced academic performance. However, 11% of the respondents stated that LE didn't affect their academic performance and attributed their performance to personal effort. The study found that socialization and interactions emerged as mediators in the learning environment - academic performance relation. Student-student interactions were more important in the lower levels than in the higher levels. Other variables found to influence academic performance

were different IEQ variables, security and modalities of assessment. [433]

Publication type: Journal article
Study type: Research study
Sample: 29 students
Duration: Single point in time
Age or developmental stage: College students

McMahon, S. D., Singh, J. A., Garner, L. S., & Benhorin, S. (2004). Taking advantage of opportunities: community involvement, well-being, and urban youth. *Journal of Adolescent Health*, 34(4), 262–265. https://doi.org/10.1016/j.jadohealth.2003.06.006

McMahon, Singh, Garner, and Benhorin address how community involvement and well-being affect urban youth and can possibly predict psychological outcomes. The methods involved in this study were 200 African American, 5th through 8th-grade students, from 3 schools and they were given surveys. The surveys measured interpersonal and community-level assessments. The questionnaire measured who students looked up to, who they wanted to be like, as well as how much they went to church, or how much did they do community-related activities. The study was for 2 years, and 4 assessments were given to students during those years. The research study found that if students had a role model there was a prediction for them to have better psychological outcomes. The study also found that if students had school-belonging they also had better psychological outcomes. Church attendance and community involvement were also predicted for students to then have better psychological outcomes. [440]

Publication type: Journal Article
Study type: Research Study
Sample: 200 Students, 3 Schools
Duration: Longitudinal, 2 Years, Cross-sectional
Age or developmental stage: 5th through 8th Grade

Raish, V., & Fennewald, J. (2016). *Embedded Managers in Informal Learning Spaces.* 16(4), 793–815.

The authors discuss the learning commons as an informal learning space on university campuses, and as a "third place" as described by Oldenburg, informal places outside of home and work where people interact, learn/study, and otherwise live their lives. The researchers identified informal learning commons which staffed "embedded managers" within the spaces, people whose job was to ensure students were comfortable, could use the technology, and provide other support. Using mixed method case study tools, such as observation and interviews, the researchers gained an inside perspective on the managers of three informal learning commons on the campus of Penn State University. Overall, the managers of the three spaces felt an obligation to ensure student comfort and to provide adequate assistance. The researchers identified six themes from their case study with the space mangers: 1) Patterns of space use, 2) Managers' perceptions of their place in the space, 3) Challenges with managing the space, 4) Relationships with stakeholders, 5) Creating a welcoming environment or third space, and

6) Rules and regulations. [437]

Publication type: Journal article
Study type: Case study
Sample: Three managers
Duration: One month
Age or developmental stage: University

Wolsey, T. D. V., & Uline, C. L. (2010). Student Perceptions of Middle Grades Learning Environments. *Middle School Journal*, 42(2), 40–47. https://doi.org/10.1080/00940771.2010.11461755

This study uses student's perceptions of the built environment to understand how they use the school and interact with each other, as well as with teachers and administrators. For their research, the authors used Dell Middle School in the US, which they selected because its students represented a range of socioeconomic and racial backgrounds. Five students were selected, and these students were instructed to take ten Polaroid photographs (each) of significant places at the school that impacted their learning, and to title the photographs. After the photos were taken, they were compiled in a "photo album", and students were interviewed about their photos. This information was analyzed and presented in discussion and conclusions. Overall, the most important takeaways by the authors were the importance of flexible learning spaces, and thoughtfully designing both social and personal spaces. Many students photographed "in-between" spaces - like thresholds or backstage areas - or objects - like desks and podiums, which the authors used to highlight the importance of school spaces outside the main classroom environment. [434]

Publication type: Journal article
Study type: Research study
Sample: 5 students
Duration: Single point in time

Safety and Security

Aldridge, J. M., Fraser, B. J., Fozdar, F., Ala', K., Earnest, J., & Afari, E. (2016). Improving Schools Students' perceptions of school climate as determinants of wellbeing, resilience and identity. 19(1), 5–26. https://doi.org/10.1177/1365480215612616

In this research study, the authors examined the connection between school climate factors (six total) and student wellbeing, life satisfaction, ethnic identity, moral identity, and resilience. Participants included N=2,202 students from six high schools in Perth, Australia. School climate was measured through teacher support, peer connectedness, school connectedness, affirming diversity, rule clarity and reporting and seeking help. The data was analyzed by a structural equation model (SEM). The results show that all six of the school climate factors were related to student wellbeing. Teacher support,

school connectedness and affirming diversity had a direct influence on student wellbeing, whereas peer connectedness, rule clarity and reporting and seeking help was mediated through students' ethnic and moral identity, resilience and life satisfaction. Overall, this study suggests that school climate is highly influential on student perceived wellbeing. [472]

Publication type: Journal article
Study type: Research study
Sample: N=2,202 students
Age or developmental stage: High schools

Aldridge, J., & Ala'i, K. (n.d.). Assessing students' views of school climate: Developing and validating the What's Happening In This School? (WHITS) questionnaire. Improving Schools, 16(1), 47–66. https://doi.org/10.1177/1365480212473680

This article describes the process of developing a six-scale survey on school climate in relation to student perception of feelings of belonging and connectedness, as well as perception of student bullying. Overall, the development of the survey included a review of the research behind school climate and factors that are effective for schools comprised of diverse students, understanding/exploring the scales identified in the research, and lastly, creating questions for the survey (as well as adapting questions from previous surveys). The questionnaire was then given to N=4,067 high school students across eight schools. Statistical analysis of the survey ensured the questionnaire's discriminant, convergent, concurrent and predictive validity. [471]

Publication type: Journal article
Study type: Theory development
Sample: N=4,067 high school students
Age or developmental stage: High schools

Barrett, S. B., Bradshaw, C. P., & Lewis-Palmer, T. (2008). Maryland statewide PBIS initiative: Systems, evaluation, and next steps. *Journal of Positive Behavior Interventions*, 10(2), 105–114. https://doi.org/10.1177/1098300707312541

Positive Behavioral Interventions and Supports (PBIS) has gained recent attention for addressing bullying in schools. However, most research on PBIS is predominately focused on elementary and middle schools. Therefore, Barrett, Bradshaw and Lewis-Palmer study the effects of PBIS implementation in high schools, and which schools are more willing to adopt this model. In their research, they randomly selected 31 out of 58 high schools to implement PBIS policies. They then analyzed the levels of bullying in the schools for a duration of two years. Overall, the high schools that had higher levels of bullying and other disorder issues were more willing to implement PBIS than those with lower levels. [465]

Publication type: Journal article
Study type: Research study
Sample: N=58 high schools

Duration: Two years
Age or developmental stage: High schools

Barrett, P., & Zhang, Y. (2012). Teachers' views on the designs of their primary schools. *Intelligent Buildings International,* 4(2), 89–110. https://doi.org/10.1080/17508975.2012.672305

In this paper the authors assess the layout and design of five schools and gather pupils' and teachers' perceptions on what constitutes a good learning environment concerning comfort and function. Regarding environmental comfort they gathered information on thermal, daylight, views, acoustic and air quality conditions and compared them with perceptions. Regarding functionality they did surveys of the buildings and gathered perceptions on the flexibility of space, color, furniture, interactive technology, storage, outdoor environment and overall impression. In this paper they only present the results of teachers' perceptions. The main takeaways from teachers' perceptions include: The main sources of high noise come from inside the school, classrooms are not too cold but can get too hot in the summer, air quality was not perceived as a problem, daylighting was appreciated but could cause some issues with glare depending on blinds. Some of the predicted positive responses that researchers expect from teachers' responses include personalization and display for the pupils, good furniture and information and communication technology, opportunities for user control and access to outdoor spaces.[464]

Publication type: Journal article
Study type: Research study
Sample: teachers in 5 schools
Duration: Five years

Bosworth, K., & Judkins, M. (2014). Tapping Into the Power of School Climate to Prevent Bullying: One Application of Schoolwide Positive Behavior Interventions and Supports. *Theory into Practice*, 53(4), 300–307. https://doi.org/10.1080/00405841.2014.947224

The authors in this article review current research on school-wide PBIS (Positive Behavioral Interventions and Supports) as a measure for bullying prevention. Overall, PBIS is a framework that focuses on teaching and acknowledging positive behavior, while also addressing conditions that lead to problem behavior among youth. The theory is grounded in behaviorism, social learning theory, prevention science and systems change. In their review, the authors found that schools which have implemented PBIS practices have reported less bullying and student victimization, fewer problem behaviors, and increased feelings of safety. [468]

Publication type: Journal article
Study type: Literature review

Bradshaw, C. P. (2013). Preventing Bullying through Positive Behavioral Interventions and Supports (PBIS): A Multitiered Approach to Prevention and Integration. *Theory into Practice*, 52(4), 288–295. https://doi.org/10.1080/00405841.2013.829732

This article explores the theory of Positive Behavioral Interventions and Supports (PBIS), a framework aimed at bullying prevention across the United States school system. Throughout the article, the author connects bullying, school climate, and positive approaches to behavior management. In addition, PBIS also serves as a framework for reducing youth violence, with the model breaking down into different tiers of prevention. [466]

Publication type: Journal article
Study type: Theory development

Breux, P., & Boccio, D. E. (2019). Improving schools' readiness for involvement in suicide prevention: An evaluation of the creating suicide safety in schools (CSSS) workshop. *International Journal of Environmental Research and Public Health*, 16(12). https://doi.org/10.3390/ijerph16122165

This qualitative study examined teacher's attitudes and readiness to suicide prevention and procedures after the one-day Creating Suicide Safety in Schools (CSSS) workshop training. Before taking the CSSS training, 562 school based mental health professionals in New York State were given a pre-test survey to determine their attitudes about the importance of school-based suicide prevention, knowledge of best practices, perceptions of administrative support, and feeling able to work collaboratively enhance school safety. After 3-months, the same group filled out a post-training survey about the school implementation policies and awareness methods. Here, survey participants stated that there were barriers to implementing change, mostly due to not enough time and the associated stigma with suicide. This outcome demonstrates that CSSS is a potentially helpful method to suicide awareness and prevention in schools, although this method needs to be further studied. [441]

Publication type: Journal article
Study type: Research Study
Sample: 562 school based mental health professionals
Duration: 3-month period
Age or developmental stage: High school

D~mean, D. (2012). A validity study of the SSP-School Inclusion Questionnaire. In *Journal of Social Research & Policy* (Vol. 3). www.schoolsuccessprofile.org

This study aimed to identify the factors influencing inclusion of disadvantaged students in high school. The questionnaire was distributed to 480 students aged 15-19 in an urban area of Romania. Likert scales were used to determine the level of inclusion and the perception of school as an educational environment. These categories included school (learning climate and school satisfaction), teachers (teacher support, academic relevancy and academic rigor), safety (school safety, personal safety, and non-victim status), and lastly performance (school engagement, trouble avoidance, and grades). The outcome showed that student who had a high level of school satisfaction

and perceive the learning climate as positive are more engaged in school. This also applies for students who have a positive perception of the teachers. However, no significant relation was found between school engagement and school safety. [442]

Publication type: Journal article
Study type: Research study
Sample: 480 students, aged 15019
Duration: Single point in time
Age or developmental stage: High school

De Waal, E., & Grösser, M. (2014). On safety and security in education: Pedagogical needs and fundamental rights of learners. ***Educar***, 50(2), 339. https://doi.org/10.5565/rev/educar.44

This study aims to shed awareness on pedagogical security of students in the classroom and different learning/teaching techniques. The research was conducted in South Africa's D7 district. The sample consisted of schools (N=18; 9 primary and 9 secondary), educators (N=244), and students (N=520). Data was obtained through two self-administered questionnaires to both the students and teachers, which focused on teaching practices in the classroom. The goal of the questionnaires was to better understand the current teaching practices in regard to the pedagogical needs of students, and to determine if different learning styles were being accommodated. Overall, the responses showed that the pedagogical needs of the onverger/senser and the diverger/watcher students were met, while other learning styles were discarded. Further, the data revealed that educators did not feel empowered to meet the pedagogical needs of the other types of learners in the classroom. [453]

Publication type: Journal article
Study type: Research study
Sample: Students (N=520), Teachers (N=244), Schools (N=18; 9 primary, 9 secondary)
Duration: Single point in time
Age or developmental stage: Primary and secondary education

Farley, T. A., Meriwether, R. A., Baker, E. T., Watkins, L. T., Johnson, C. C., & Webber, L. S. (2007). Safe play spaces to promote physical activity in inner-city children: Results from a pilot study of an environmental intervention. *American Journal of Public Health*, 97(9), 1625–1631. https://doi.org/10.2105/AJPH.2006.092692

In this field study, the authors provided safe play areas for inner city school children in order to evaluate the effect of safety on physical activity levels and obesity. In the intervention neighborhood, the authors provided safety attendants to watch over the play-yard; in the comparison play-yard, no attendant was provided. Observations occurred over a two-year period. On average, in the intervention play-yard, 71.4 children used the area on the weekdays and 25.8 children used the area during the weekends (during the school year). Overall, the number of children who used the playground were 84% higher than the comparison neighborhood. This observational study demonstrates how providing safe play areas increases physical activity and

provides obesity prevention. [443]

Publication type: Journal article
Study type: Field Study
Duration: Two-year period
Age or developmental stage: Elementary school

Finell, E., Tolvanen, A., Haverinen-Shaughnessy, U., Laaksonen, S., Karvonen, S., Sund, R., Luopa, P., Pekkanen, J., & Ståhl, T. (2017). Indoor air problems and the perceived social climate in schools: A multilevel structural equation analysis. https://doi.org/10.1016/j.scitotenv.2017.12.126

In this research study, the authors are interested in the relationship between indoor air problems and associated student-teacher relations and class spirit. In a nationwide sample of Finnish schools (N=194 schools, n= 27,153 students), data of the schools' social climate was merged independently with data on observed indoor air problems (using multi-level structural equation modeling). The analysis shows that in schools with observed indoor air problems, the teacher-student relationship and student morale (only among students with a high-grade point average) were both worse than in schools with no observed indoor air problems. These findings conclude that indoor air problems affect student's perceived school climate.[469]

Publication type: Journal article
Study type: Research study
Sample: N=194 schools, n= 27,153 students

Fuxa, A. J., & Fulkerson, J. A. (2011). Adolescent Obesity and School Performance and Perceptions of the School Environment Among Minnesota High School Students. *School Mental Health*, 3(2), 102–110. https://doi.org/10.1007/s12310-011-9050-0

This meta-analysis research study examined the relationships between adolescent obesity, school performance, perceptions of the social environment, and safety at school. The authors analyzed data from the Minnesota Student Survey (n=87,468 students) administered in the spring of 2007 in relation to their weight status using a logistic regression and linear modeling. The questionnaire focused on grade achievement, skipping school, future school plans, perceptions of the social environment, and safety in school. Overall, the cross-analysis showed that overweight and obese high schoolers were significantly less likely to plan to go to college, more likely to skip school because of fear of safety, lower academic grades, and negative perceptions about the social environment and safety in school in comparison to the non-overweight students (all $p<0.001$). [444]

Publication type: Journal article
Study type: Meta-analysis
Sample: 87,468 students
Duration: Spring, 2007
Age or developmental stage: High school

Goldweber, A., Waasdorp, T. E., & Bradshaw, C. P. (2013). Examining the link between forms of bullying behaviors and perceptions of safety and belonging among secondary school students. https://doi.org/10.1016/j.jsp.2013.04.004

This research study aimed to understand the connection between student bullies and the perception of school climate. Within a sample of N=10,254 middle school students, and n=2,509 high school students, person-centered analyses were used to identify district groupings of bullying behavior and social-emotional factors (such as victimization, internalizing, and perception of school and bullying climate). For the middle school, four classes were displayed (Low Involvement, Verbal, High Physical/High Verbal, and High Involvement), and for high school, three groups (Low Involvement, Verbal, and High Involvement). Overall, most student classes were categorized in the "low involvement" bullying class. The "high involvement" bullying class was the smallest sample (1.6% middle; 7.3% high school), however students in this situation reported higher feelings of victimization, feeling less safe, less belonging, and perceived the school as supportive of bullying (such as adult intervention ineffective). In the middle school, the "high physical/high verbal" class reported higher levels of victimization, in comparison to the "verbal" class. These findings demonstrate the heterogeneity of bully behaviors and highlight the importance of prevention and intervention in schools to address safety and belonging. [470]

Publication type: Journal article
Study type: Research study
Sample: N=10,254 middle school students, n=2,509 high school students
Age or developmental stage: High school, middle school

Glew, G. M., Fan, M.-Y., Katon, W., & Rivara, F. P. (2008). Bullying and School Safety. *J Pediatr*, 152(1). https://doi.org/10.1016/j.jpeds.2007.05.045

In this cross-sectional study, 5,391 students in seventh, ninth, and eleventh grade in an urban school were given a thirty-four-question survey for the school's annual internal climate review. Of the thirty-four questions asked, three questions were about bullying. Overall, 26% of students were involved in bullying (either a victim, bully, or as a bully-victim). The results showed that all three groups were more likely to feel sad during the school day than the students who identified themselves as bystanders. Victims were more likely to believe that they were "no good," and to feel that they "do not belong" in school. The odds of being a victim (instead of a bystander) were 10% lower for every 1 point higher in GPA. Bully-victims also had a higher likelihood of feeling like they were "no good" and were more likely to say that bringing a gun to school is "not wrong." Overall, this study reinforces the notion that school environment is interrelated with mental health and school success. [450]

Publication type: Journal article
Study type: Research study
Sample: 5,391 students
Duration: Single point in time
Age or developmental stage: Seventh, ninth and eleventh grade

Hawe, P., Bond, L., Ghali, L. M., Perry, R., Davison, C. M., Casey, D. M., Butler, H., Webster, C. M., & Scholz, B. (2015). Replication of a whole school ethos-changing intervention: different context, similar effects, additional insights. https://doi.org/10.1186/s12889-015-1538-3

In this study, the researchers replicated the Australia Gatehouse Project, a community-based intervention approach intended make students feel safe, connected and valued in school, in a rural Canadian high school. A risk behavior survey was given to students in tenth through twelfth grade before the intervention, and then given again after the intervention two years later. The strategies in the intervention included changes in teaching practices, orientation procedures, professional development for staff, a stronger student voice, and encouraging student proactivity and participation. Changes in health and health risk behaviors were analyzed over that two-year period. Overall, there was no statistically significant reduction in depression or bullying. For girls, there were statistically significant decreases in low school engagement, drinking, unprotected sex, and poor health. However, none of these results were significant for boys. Overall, results from interventions conducted at similar school environments were similar, although this research indicates that behavior change in school is highly context dependent. [460]

Publication type: Journal article
Study type: Research study
Duration: Two years
Age or developmental stage: Canadian high school (10^{th}-12^{th} grade)

Hernández, M. M., Robins, R. W., Widaman, K. F., & Conger, R. D. (2017). Ethnic pride, self-esteem, and school belonging: A reciprocal analysis over time. *Developmental Psychology*, 53(12), 2384–2396. https://doi.org/10.1037/dev0000434

This study focused on the association between Mexican ethnic pride, self-esteem, and feelings of belonging in school children. The researchers used data from a longitudinal study of Mexican-origin students (N=674, mean age =10.4 years, 50% girls), evaluating them from fifth to ninth grade, along with multiple group analysis in a structural equation modeling framework. The results show that among boys, ethnic pride is associated with increased self-esteem, which is then associated with school belonging. For girls, ethnic pride was associated with school belonging, but not necessarily with self-esteem. This conclusion shows that gender differences between the two should be understood when implementing school programs for school pride, self-esteem, and ethnic pride.[456]

Publication type: Journal article
Study type: Meta-analysis
Sample: N=674, mean age =10.4 years, 50% girls
Duration: Fifth to ninth grade
Age or developmental stage: Middle school

Hošková-Mayerová, Š., Bekesiene, S., & Be~ová, P. (2021). Securing Schools against Terrorist Attacks. *Safety*, 7(1), 13. https://doi.org/10.3390/safety7010013

This qualitative study focused on the safety and security of schools in Brno,

Czech Republic. The authors interviewed school principals with fifteen questions about school security in nursery, elementary and secondary schools. Through the interviews, it was found that most schools in the area had a basic level of security. The most effective tool for deterring an attacker was to have a school security officer who would monitor the school and check the entry/exits. [452]

Publication type: Journal article
Study type: Research study – qualitative
Duration: Single point in time
Age or developmental stage: Nursery, elementary, and secondary schools

Jóhannsdóttir, T. (2018). Creating a school that matters: networking for school-community development. *Journal of Curriculum Studies*, 50(3), 297–314. https://doi.org/10.1080/00220272.2017.1337812

In this study, the researcher focuses on the creation of a new upper secondary school in Iceland, and the impacts of collaboration on school community and practice. Over a three-year period, the author used ethnographic methods to understand how issues and contradictions were handled in the school by administration, and how that effected the cohesiveness of the school. Overall, the principal's clear vision for premier education, coupled with societal support of the curriculum, helped facilitate the development of the school and created an atmosphere of cohesive and community-based decision making even amongst disagreements and issues. [458]

Publication type: Journal article
Study type: Research study
Duration: Three-year period
Age or developmental stage: Upper secondary school (Iceland)

Jones, S. E., Axelrad, R., & Wattigney, W. A. (2007). Healthy and safe school environment, part II, physical school environment: Results from the school health policies and programs study 2006. *Journal of School Health*, 77(8), 544–556. https://doi.org/10.1111/j.1746-1561.2007.00234.x

Jones, Axelrad, and Wattigney address the health and safety of schools with a program that occurs every six years and measures the health of schools and the effect schools have on students. The methods involved in this study were a program for the Center for Disease Control and Prevention that analyzes the health and safety at schools. The state education agency personnel completed a self-administered questionnaire or a computer-assisted telephone interview that addressed the health and safety of schools. 424 school districts and 992 elementary, middle, and high schools were a part of the study. The study found that 51.4% of schools had indoor air quality programs that managed IAQ at school. Hazardous materials are an issue of safety and most schools and districts had programs that addressed them. The study also found that only 24.5% of schools and districts had pest management programs. Only 13.4% of districts had green design included as a policy when building or renovating buildings.[477]

Publication type: Journal Article
Study type: State Research Study
Sample: 424 school districts, 992 schools
Duration: Longitudinal, one year, Cross-sectional
Age or developmental stage: Elementary, Middle, and High School

Kantun, S., Sedyati, R. N., & Fitriati, I. (n.d.). IOP Conference Series: Earth and Environmental Science Improving Students' environmental care behavior through the Implementation of the green and clean school program in SMP Negeri 1 Jember. https://doi.org/10.1088/1755-1315/243/1/012091

In this field report, the authors examine the implementation and effectiveness of the Green and Clean School Program in an Indonesian school (SMP Negeri 1 Jember). Through observations, interviews and documents, the authors collected data from (1) principal, (1) vice principal, (2) social studies teachers, (1) janitor, (1) food sellers, and (4) students. The results show that the implementation of the program has been good, however it has not been maximized to its full potential. Factors that hinder the implementation of the program are as follows: the imbalance between land and the number of classes; lack of available planting material; lack of student awareness and involvement in preserving the environment; and lack of people who understand the program. The school plans to optimize the program through these strategies: enforce environmental preservation rules for students; maximize the use of classrooms; use the yard as much as possible; and increase contact with environmental agencies. Overall, this study suggests that the Green and Clean School program can be effective if the school is able to implement it properly. [474]

Publication type: Journal article
Study type: Field study
Sample: N=6 school employees; n=4 students

Kittelman, A., Mcintosh, K., & Hoselton, R. (2019). Adoption of PBIS within school districts. https://doi.org/10.1016/j.jsp.2019.03.007

In this study, researchers investigated the rate at which PBIS, Positive Behavioral Intervention and Supports, has been implemented in school districts. Overall, the study included 552 districts within twenty-five U.S. states that were adopting the PBIS framework. Over the first four years of the study, PBIS adaption increasingly grew throughout these districts, with growth slowing after year four. In looking at the factors that impact and increase PBIS implementation, the researchers concluded that district size, the number of students receiving free or reduced lunch, and urban districts were more likely to adopt PBIS strategies. [462]

Publication type: Journal article
Study type: Research study
Sample: 552 school districts across 25 U.S. states
Duration: Five years

Lamoreaux, D. J., & Sulkowski, M. L. (2021). Crime Prevention through Environmental Design in schools: Students' perceptions of safety and psychological comfort. *Psychology in the Schools*, 58(3), 475–493. https://doi.org/10.1002/pits.22459

Lamoreaux and Sulkowski address how crime rates are affected by perceptions of psychological comfort and safety at school by students. The methods involved in this research study were 900 middle school and high school students from 4 different school districts. The study measured with an electronic collection of data, which was the perception of students. The measurements were taken of preferences of the safety of the physical environment and psychological comfort. The study also compared the results with a match-paired research design. The study found that the Crime Prevention through Environmental Design (CPTED) strategies for design could involve access control, territoriality/maintenance, and natural surveillance. The study also found that those strategies resulted in students perceiving them as bringing more psychological comfort and were physically safe. The study also found that demographic differences in the students did not impact outcomes in perceived relationships about safety and comfort. The study also found that the CPTED strategies could be used to create a comfortable environment for students. [478]

Publication type: Journal Article
Study type: Research Study
Sample: 900 students, 4 school districts
Duration: Longitudinal, Cross-sectional
Age or developmental stage: Middle School and High School

Lamoreaux, D., & Sulkowski, M. L. (2020). An alternative to fortified schools: Using crime prevention through environmental design (CPTED) to balance student safety and psychological well-being. *Psychology in the Schools*, 57(1), 152–165. https://doi.org/10.1002/pits.22301

Lamoreaux and Sulkowski address how the built environment can help prevent crimes at schools and the effect the built environment has on the safety and psychological well-being of students. The methods involved in this study were several studies that address safety and crimes in schools and the effect they had on the psychological well-being of students, as well as the Crime Prevention through Environmental Design philosophy. The study measured student outcomes, security measures, relationships between academic performance and perceptions of safety, and how the CPTED could influence the factors. The literature review focused on criminal and antisocial behaviors that are affected by environmental design. The study and review found that school security impacts students and security features that are visible sometimes increase worries of students about the safety of the environment they are in. The study and review also found the safety perceptions are an important aspect to consider, as well as design principles that are not too overbearing that may cause distractions for students. [479]

Publication type: Journal Article
Study type: Research Study/Literature Review
Sample: Several Texts
Duration: Cross-sectional
Age or developmental stage: K-12

Lee, C.-K. J., & Huang, J. (2021). The relations between students' sense of school belonging, perceptions of school kindness and character strength of kindness. *Journal of School Psychology,* 84, 95–108. https://doi.org/10.1016/j.jsp.2020.12.001

This study examined the relationships between secondary school students' sense of school belonging, their perception of school kindness, and character strength of kindness. Additionally, the study aimed to understand the perception difference between genders. Data was collected from N=1973 secondary school students, 55.2% of which were girls. Research was conducted in Hong Kong, China, during the second semester of 2017-2018 school year (April to June 2018). The findings show that students' sense of belonging was positively correlated with perceptions of school kindness and student kindness. Girls reported higher levels of personal kindness than boys. Overall, the study provides a better understanding of how perceived kindness is related to a sense of belonging. [473]

Publication type: Journal article
Study type: Research study
Sample: N=1973 students
Duration: April to June 2018
Age or developmental stage: Secondary school

Lumpkin, R. B., Goodwin, R. T., Hope, W. C., & Lutfi, G. (2014). Code compliant school buildings boost student achievement. *SAGE Open*, 4(4). https://doi.org/10.1177/2158244014556993

Lumpkin, Goodwin, Hope, and Lutfi address how student achievement is affected by code-compliant school buildings. The methods involved in this empirical research study were a casual-comparative research model, 33 school districts, with 69 combination schools, 190 high schools, 126 middle schools, and 405 elementary schools. The study measured the student achievement of 30,655 10th graders, 34,135 9th graders, 33,938 8th graders, and 35,889 4th graders based on their school's compliance to code. The study was for one year during 2000 and involved mathematics and reading subtests of the FCAT. The control groups were two groups of 10th, 9th, 8th, and 4th graders who had school in old buildings. The experimental group was two groups of 10th, 9th, 8th, and 4th graders who had school in new buildings. The study found that there was an increase in the number of students who were passing the reading and mathematics subtests for the FCAT in the new buildings that were up to code.[480]

Publication type: Journal Article
Study type: Empirical Research Study
Sample: 33 districts, 69 combination schools, 190 high schools, 126 middle schools, and 405 elementary schools. 30,655 10th graders, 34,135 9th graders, 33,938 8th graders, and 35,889 4th graders.
Duration: Cross-sectional, Longitudinal, One Year
Age or developmental stage: 4th, 8th, 9th, and 10th Grade

Mclaughlin, E. A. (2013). Design charrette as methodology for student learning assessment relative to building safety and security. *Journal of Interior Design*, 38(2), 35–46. https://doi.org/10.1111/joid.12005

Mclaughlin addresses how student learning is affected by understanding the safety and security of a building. The methods involved in this exploratory pedagogic study were building interior design students who applied security and safety strategies in different scenarios to understand supplementary techniques and building codes. The study measured the ability of students to assess how safe a building was and to understand the effects that security has on them. The study also measured the ability of students to assess the security of a building. The study used charrette as an instructional method during the measurements and totality of the study. The exploratory pedagogic study found that study-based course work should use a charrette as an instructional method to reinforce the ideas of security and safety. The study found that students need to fully understand how their design can impact the security and safety of buildings and to keep them in mind when creating spaces. [481]

Publication type: Journal Article
Study type: Exploratory Pedagogic Study
Sample: 1 School
Duration: Cross-sectional, Longitudinal
Age or developmental stage: Graduate

Molloy, L. E., Moore, J. E., Trail, J., James, J., Epps, V., Hopfer, S., Molloy, L. E., Moore, J. E., Trail, J., Van, J. J., & Hopfer, S. (n.d.). Understanding Real-World Implementation Quality and "Active Ingredients" of PBIS. https://doi.org/10.1007/s11121-012-0343-9

Positive Behavioral Intervention and Supports, a school based behavioral intervention method, is evaluated across multiple schools to better understand how it has been implemented in different systems and the quality of its practice. Overall, data from 27,689 students (from 166 public primary and secondary schools across seven states), was gathered to further analyze student demographics, PBIS implementation quality, and reports of problem behavior during the 2007-08 school year. In this meta-analysis, results show that many schools are failing to implement PBIS properly, and that there were several differences between the schools that led to differences in PBIS quality. The researchers concluded that more analysis of "real world" implementation needs to occur in order to improve the roll-out and quality of intervention policies in schools. [461]

Publication type: Journal article
Study type: Meta-analysis
Sample: N=27,689 students; 166 primary and secondary schools, seven U.S. states
Duration: 2007-2008 school year
Age or developmental stage: Primary and secondary education

Mori, Y., Tiiri, E., Khanal, P., Khakurel, J., Mishina, K., & Sourander, A. (2021). Feeling Unsafe at School and Associated Mental Health Difficulties among Children and Adolescents: A Systematic Review. Children (Basel, Switzerland), 8(3), 232. https://doi.org/10.3390/children8030232

This study reviewed the current literature on perceived school safety across five different databases. The authors reviewed 43 papers in total, analyzing the associations between mental health and perceived safety among children and adolescents. The literature search concluded on February 9, 2021. Overall, the findings revealed that 19.4% (mean prevalence) of students felt unsafe at school, with a range from 6.1% to 69.1% depending on the study. Lack of perceived safety was related to feeling victimized, along with mental health difficulties (such as depression and suicidal behavior). Higher perceived safety was associated with a security officer on-site and fair enforcement of school rules. Overall, the review did not contain cross-cultural studies, which the authors stated should be examined going forward. [449]

Publication type: Journal article
Study type: Literature review
Sample: 43 papers – 5 databases
Duration: Longitudinal
Age or developmental stage: Children and adolescents

Nasrudin, N., & Nor, A. R. M. (2013). Travelling to School: Transportation Selection by Parents and Awareness towards Sustainable Transportation. *Procedia Environmental Sciences*, 17, 392–400. https://doi.org/10.1016/j.proenv.2013.02.052

In this study, 98 questionnaires were randomly distributed to low-income and middle-income families living in Section 7, Shah Alam, Selangor, Malaysia (population of 37,415). The purpose of the questionnaire was to understand the motivating factors behind a parent's decision for school transportation, and to investigate attitudes towards sustainable transportation. The data showed that most parents used private transportation to send their children to school because they were concerned with safety and security (crime and traffic). As a result, parents were not interested in sustainable transportation, even though they were aware of the many positive benefits of walking to school. In conclusion, improving public security will encourage parents to use sustainable transportation options (such as allowing their children to walk or cycle to school). [451]

Publication type: Journal article
Study type: Research study
Sample: 98 participants
Duration: Single point in time
Age or developmental stage: Children

Nieuwenhuis, J., & Hooimeijer, P. (2016). The association between neighbourhoods and educational achievement, a systematic review and meta-analysis. *Journal of Housing and the Built Environment*, 31(2), 321–347. https://doi.org/10.1007/s10901-015-9460-7

Nieuwenhuis and Hooimeijer address how neighborhoods, where students

live, affect their educational outcomes, specifically their educational achievements. The methods involved in this systematic meta-analysis review were 5,516 articles that were narrowed down to 88 depending on criteria and relevance and they address relationships between educational outcomes and neighborhoods. The review measured, with meta-regression, the poverty, educational climate, social disorganization, and proportion of ethnic and migrant groups in neighborhoods. The review also measured the level of segregation, gender composition, age composition, the individual previous attainment, parenting, schools, and family SES. The systematic review and meta-analysis found that there was a difference between the articles studying the differences in the type of model used and sampling design used in each study. The systematic review and meta-analysis also found that control variables, such as parenting, school, and family SES, can explain why the effects of neighborhoods have on educational achievement vary. [482]

Publication type: Journal Article
Study type: Systematic Review and Meta-analysis
Sample: 88 studies/articles
Duration: Cross-sectional, Longitudinal
Age or developmental stage: 4 to 21+ Years Old

Oluyomi, A. O., Lee, C., Nehme, E., Dowdy, D., Ory, M. G., & Hoelscher, D. M. (2014). Parental safety concerns and active school commute: Correlates across multiple domains in the home-to-school journey. *International Journal of Behavioral Nutrition and Physical Activity*, 11(1). https://doi.org/10.1186/1479-5868-11-32

This study is a cross-sectional meta-analysis of the relationship between traffic safety, parental safety concerns, and walking to school (WTS) programs in the United States. The survey included parents of 4th grade students (n=830) attending 81 elementary schools across Texas and who lived within two miles of the children's school. Overall, around 18% of parents allowed their children to walk to school on most days. For traffic safety concerns, parents were more likely to allow their children to walk to school if there were high sidewalks, well maintained sidewalks, and safe road-crossings. Furthermore, walk to school was more likely if there was "no problem" with traffic speed, amount of traffic, sidewalks/pathways, intersections/crossing safety, and crossing guards. Additionally, parents were more likely to agree to WTS if there was a low possibility of stray animals, and a large walking group of people. [445]

Publication type: Journal article
Study type: Meta-analysis
Sample: 830 parents, 81 elementary schools
Duration: Single point in time
Age or developmental stage: Elementary school

Ruiz, J. D. C., Quackenboss, J. J., & Tulve, N. S. (2016). Contributions of a child's built, natural, and social environments to their general cognitive ability: A systematic scoping review. *PLoS ONE*, 11(2). https://doi.org/10.1371/journal.pone.0147741

Ruiz, Quackenboss, and Tulve address how the cognitive ability of children

is affected by the built, natural, and social environments that surround them. Specifically, a focus on non-chemical and chemical stressors from the social, natural, and built environment. The methods involved in this paper were three databases and collected studies from 2003 to 2013 that analyzed the cognitive ability of children and exposure factors. The paper measured 258 eligible studies with the negative effects of factors, chemical exposures, or inherent factors. The paper measured the article's ability to examine social, physical, and natural factors that could potentially affect the cognitive abilities of children. The paper found that sleep health, lead and water pollutants, and parental growth showed negative effects on cognitive abilities. The lifestyle choices of the mothers showed positive associations for the cognitive ability of children. The diet of the mother of a child was also found to show positive associations for their cognitive ability. [483]

Publication type: Journal Article
Study type: Systematic Review
Sample: 258 papers
Duration: Cross-sectional, Longitudinal, 10 Years
Age or developmental stage: Birth to 18 Years Old

Saraví, G. A., Cristina Bayón, M., & Azaola, M. C. (2020). Constructing School Belonging(s) in Disadvantaged Urban Spaces: Adolescents' Experiences and Narratives in Mexico City. *Youth & Society*, 52(7), 1107–1127. https://doi.org/10.1177/0044118X19838188

This article explores school belonging among high school students in Mexico who come from disadvantaged backgrounds. The authors argue that most studies on school belonging are within the Anglo-Saxon context, so they aim to close the research gap given the difference cultural and social context. By investigating stigmatization, school climate, and social relations between teachers and peers, the authors conclude that there needs to be more professional development in disadvantaged high schools focusing on student involvement, teacher support, and social recognition.[459]

Publication type: Journal article
Study type: Theory development
Age or developmental stage: High school

Simonsen, B., & Sugai, G. (2013). PBIS in alternative education settings: Positive support for youth with high-risk behavior. *Education and Treatment of Children*, 36(3), 3–14. https://doi.org/10.1353/etc.2013.0030

This article highlights how the PBIS (Positive Behavioral Interventions and Supports) framework supports youth who display high-risk behavior at different levels. The researchers reviewed case studies of special education classrooms, elementary, middle, and high school, correctional facilities, and youth programs for behavioral needs, all which use PBIS elements. The outcomes, data, systems and practices of PBIS in these systems were then analyzed to better understand the role of PBIS in different settings. Overall, the case studies show that there are three tiers for providing support: ensuring that staff are responding to what the youth need (tier 1), intensely providing support in the group (tier 2), and lastly, work one-on-one with individuals for

personal support (tier 3). In conclusion, PBIS is a tier system which aims to support all youth, regardless of risk-behavior level. [467]

Publication type: Journal article
Study type: Literature review

Susanto, T., Sulistyorini, L., Wuryaningsih, E. W., & Bahtiar, S. (2016). School health promotion: A cross-sectional study on Clean and Healthy Living Program Behavior (CHLB) among Islamic Boarding Schools in Indonesia. *International Journal of Nursing Sciences*, 3(3), 291–298. https://doi.org/10.1016/j.ijnss.2016.08.007

This study explores student behavior, knowledge and feelings towards the Clean and Healthy Living Behavior (CHLB) in Islamic Boarding Schools (East Java, Indonesia). Participants included N=114 students (13.17 mean age) from a random sample through a cross-sectional school-based survey. Eight indicators of CHLB were analyzed: washing hands with running water and soap, eating healthy snacks, using clean and healthy latrines, exercising regularly and measurably, eradicating mosquito larvae, not smoking at school, weighing and height measurement every 6 months, and disposing garbage properly. The results focused on the knowledge, attitude and behavior towards CHLP by health education and grade. Overall, about 66.7% of students received health education, with a significant relationship between health education and knowledge in CHLP. [475]

Publication type: Journal article
Study type: Research study
Sample: N=114 students

Tanaka, K.-I., Miyashiro, R., & Miyamoto, Y. (2016). A Bi-objective Optimization Model for Designing Safe Walking Routes for School Children. *Geographical Analysis*, 48, 448–464. https://doi.org/10.1111/gean.12095

In this study, the authors used a mathematical optimization approach to better understand the safest way school children should walk to school. Here, the authors assume that the risk of walking in a group is less safe than when a child walks to/from school alone. However, the authors wanted a route that also capitalizes on the shortest walking distance for each student. Using an optimization method with integer programming, the authors were able to come up with a path that optimized both distance and amount of time walking within a group. These results show much better solution compared to when each child walks the shortest path from school to home (regardless of group size). [446]

Publication type: Journal article
Study type: Theory Development
Age or developmental stage: Children, elementary to middle school

Tanner-Smith, E. E., Fisher, B. W., Addington, L. A., & Gardella, J. H. (2018). Adding Security, but Subtracting Safety? Exploring Schools' use of Multiple Visible Security Measures. *American Journal of Criminal Justice*, 43(1), 102–119. https://doi.org/10.1007/s12103-017-9409-3

This study researched the relationship between the number of security measures in middle and high schools, in regard to the associated drug exposure, fighting, property crime, and firearms in these schools. Researchers compared school administrator-reported data with the School Survey on Crime & Survey (SSOCS) for high schools (N=6,520) and middle schools (N=3,820) over these four years: 2003-2004, 2005-2006, 2007-2008, 2009-2010. This quasi-experimental study used propensity scores to adjust for potential confounding factors. Overall, there was no evidence to support that visible security methods were associated with reduced levels of crime or violence in school. Further, the data showed that use of security personnel, cameras, and metal detectors was greatly associated with greater exposure to drugs, crime, and violence in the school system. [455]

Publication type: Journal article
Study type: Research study
Sample: Middle school students, N=3,820; High school students, N=6,520
Duration: Four years: 2003-2004, 2005-2006, 2007-2008, 2009-2010
Age or developmental stage: Middle and high school

Terzian, S. G. (2004). The Elusive Goal of School Spirit in the Comprehensive High School: A Case History, 1916-1941. https://doi.org/10.1353/hsj.2004.0021

In this historic case study, the author reviews the Ithaca High School (I.H.S) newspaper from 1916-1941 in order to understand the elements of school spirit during this timeframe. The author chooses I.H.S due to its large size, and the newspaper's popularity and longevity at the school. Overall, the author finds that the newspaper (which is written by the students) stress three important factors to school spirit: participation, loyalty, and pride. However, throughout the newspaper, there are frequent complaints about the perceived absence of school spirit, in addition to comments about how this stems directly from the administration. Overall, the author finds that administration is very influential in impacting perceived school pride, and that all three elements, participation, loyalty, and pride, need to be present in order to have healthy school spirit. [457]

Publication type: Journal article
Study type: Theory development
Duration: 1916-1941
Age or developmental stage: High school

Vanner, C. (2019). Examining gender safety in schools: Teacher agency and resistance in two primary schools in Kirinyaga, Kenya. *Education Sciences*, 9(1). https://doi.org/10.3390/educsci9010063

In this field study, the author travels to two primary schools in Kirinyaga County, Kenya to analyze the implementation and application of GSS, a framework for providing safety and equality within schools. This is part of the

global Sustainable Development Goal (SDG) of equity, inclusion, and quality education for all. The two Standards 1-8 primary schools were selected by the sub-county Education Office (one urban, one rural). The researcher collected data in two phases: the first phase involved participant observation (Jan-April 2015), and the second phase included interviews with students and teachers (April-July 2015). The sample size for the interviews was different for each of the schools due to interest, time, and reasonable representation. The findings show that individual teacher agency was the main factor enhancing GSS. However, due to hierarchical administration and a narrow goal of school responsibilities, teach agency was insufficient in implementing GSS. The researcher suggests that teachers use community-based networks to encourage gender equality and child protection policies within schools and the community. [447]

Publication type: Journal article
Study type: Field Study
Duration: January – July 2015
Age or developmental stage: Standards 1-8 primary school

Voight, A., & Nation, M. (2016). Practices for Improving Secondary School Climate: A Systematic Review of the Research Literature. In *American journal of community psychology* (Vol. 58, Issues 1–2, pp. 174–191). John Wiley & Sons, Ltd. https://doi.org/10.1002/ajcp.12074

This journal article consists of a systematic review of programs and practices for improving school climate, which has received much attention in education policy. Overall, 66 studies were identified with evidence related to nine common elements throughout the current program and practices for improving school climate. The review concludes with an understanding of the current state of the school climate, and what improvements need to be made for the betterment of the system.[476]

Publication type: Journal article
Study type: Literature review
Sample: N=66 studies

Wysoki~ska-Senkus, A. (2020). The concept of safety and security education in the context of sustainability. *Sustainability* (Switzerland), 12(12). https://doi.org/10.3390/su12125022

The purpose of this paper was to study the development of safety and security, while advocating its ties to sustainability, in Polish high schools. To gather data, the researchers used a computer-assisted web interview to discuss security and safety with different students. The first sample consisted of 418 high school students from a public school, and the second sample consisted of 100 high school students taking solitaire classes. The results from these interviews were then reviewed by 20 security and safety experts in order to understand the attitudes and knowledge level around the subject. Overall, the findings show that many students lacked knowledge around safety and security and that there were many gaps in the education for this subject. Researchers suggested that e-learning platforms, games, social media, simulators and virtual worlds, and VR googles, among others, should

be used in modern safety and security school trainings. [454]

Publication type: Journal article
Study type: Research study
Sample: 518 students
Duration: Single point in time
Age or developmental stage: High school

McIntosh, K., Kelm, J. L., & Canizal Delabra, A. (2016). In Search of How Principals Change: A Qualitative Study of Events That Help and Hinder Administrator Support for School-Wide PBIS. *Journal of Positive Behavior Interventions*, 18(2), 100–110. https://doi.org/10.1177/1098300715599960

The purpose of this study was to better understand the underlying factors and beliefs of school administrators who expressed opposition to PBIS implementation in their school. Overall, 10 school administrators were interviewed regarding their opposition to PBIS. In these interviews, researchers used Enhanced Critical incident Technique (a qualitative analysis) to extrapolate eight helping, three hindering, and two potentially persuasive experiences with PBIS that influenced the administrators' opinions. This study highlights how personal experience can hinder the implementation of PBIS. [463]

Publication type: Journal article
Study type: Research study
Sample: 10 school administrators

Xaba, M. (2006). An investigation into the basic safety and security status of schools' physical environments. *South African Journal of Education EASA* (Vol. 26, Issue 4). https://doi.org/10.4314/saje.v26i4.25091

This is an observational field-study on the safety of the physical environment of schools in South Africa. The author argues that the safety and security of a school's physical environment is crucial to the overall safety and security of a school, and therefore should be the starting point of any school safety analysis. In their observations, it was discovered that while South African schools had some measure of basic physical security, more focus is needed on security maintenance, functionality of surveillance systems, and collaboration with outside security companies (like law-enforcement). [448]

Publication type: Journal article
Study type: Field Study
Age or developmental stage: High school

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