Spring 2025

Syllabus

ARCH-7362 Healthy Buildings: Science and Application

Updated on 12/1/2024

Location: Meyerson Hall B5

March 20, 2025 - May 1, 2025

Thursdays, 5:15pm - 8:15pm

Instructor: Jie Zhao, PhD

jzhaonyc@upenn.edu

Healthy Buildings: Science and Application is a seven-week graduate level course that examines the scientific evidence of how different elements of the indoor environment impact human health and well-being, and discusses practical design and technology applications for offices, homes, schools and other spaces.

We spend 90% of our time indoors. Understanding the interaction between the built environment and human health has never been more important. The notion that your indoor environment can make you happier, healthier and more productive is well accepted. There is increasing demand for the knowledge and experience in healthy buildings from architectural design firms, corporate workplace strategies, real estate management and investment, as well as technology companies. Corporations and consumers are willing to pay more to improve the spaces where they work, live and play.

The interdisciplinary scientific evidence of how different elements of the indoor environment can impact our health and well-being is abundant and growing. Years of public health studies have shown that air quality, water quality and material safety have profound and quantifiable impacts to our physical and mental health, and directly contribute to the global burden of diseases. Emerging studies in the fields of neuroscience and psychology have shown convincing evidence that light and biophilic design elements can impact people's mental health. Building scientists have extensively studied the impact of thermal, acoustic and

ergonomic comfort in different spaces for different people. Recently, the behavioral economics concepts of nudges and persuasive technologies have also been adopted by the building industry to encourage occupants to adopt healthier lifestyles. This course will introduce all the scientific evidence mentioned above, and specifically focus on lighting design for people's health and well-being.

As an architecture student, you need to first understand art and science, and then balance form and function. This course focuses on explaining the science and inspires you to design for function. Of course, art and form would always be embedded in every step of the design project.

The goals of the course are to:

1. Form the mindset of healthy building design;
2. Understand the state-of-the-art science of healthy buildings and how built environments impact people;
3. Discuss and evaluate design and technology solutions in different aspects of the built environments with a focus on lighting and biophilic design;
4. Apply healthy building design and technology solutions (with a focus on lighting, biophilia and nudge design) to a practical design project.

This course has three components to support students achieving the learning objectives outlined above. The lectures mainly focus on providing the theoretical framework of the science of healthy buildings. The presentation and discussions mainly focus on evaluating and researching on design and technology solutions following the topics of the lectures.

There are no prerequisites for this course. However, students with knowledge and experience in architecture, architectural engineering and other related fields would benefit more from this course. At the end of the course, students are expected to understand the science behind healthy buildings and can incorporate these knowledge and mindset in their design projects.

Course Schedule

Date	Week #	Topics of the lectures	Assignments
March 20	Week 1	Why healthy buildings? Public health and cost benefit	Reading Project assignment 1 - choose project topic
March 27	Week 2	Air, water, thermal, sound, and material	Reading Project assignment 2 - define project goal and

			concept
April 3	Week 3	Science of light and health Project Presentation 1	Reading Project assignment 3 - define light and health goal for the project
April 10	Week 4	Human-centric daylighting and lighting Project Presentation 2	Reading Project assignment 4 - daylighting and lighting design
April 17	Week 5	**Guest lecture: TBD** Biophilic design	Reading Project assignment 5 - biophilic design
April 24	Week 6	Guest lecture: Carolyn Swope Nudge design	Final design project
May 1	Week 7	Final project presentation	Submit final design project

The three hour class time would typically be separated into six parts:

- Discussion of the previous reading assignment: 10 minutes
- Lecture: 60 minutes
- Break: 10 minutes
- Lecture: 45 minutes
- Project presentation/discussion: 45 minutes
- Wrap up and issue assignment: 10 minutes

Grading criteria

The performance evaluation of this course is based on reading assignments (10%), attendance, project assignments, in-class presentations and discussions (30%), and the final course project deliverable and presentation (60%).

Students are expected to complete reading assignments as indicated on this syllabus and course lectures, and to participate in the discussion about the reading assignment from the previous week. This accounts for 10% of the final grade.

During week 1, students would learn the high-level concepts of healthy buildings. Students are required to form a team of two people and choose a topic as their project.

From week 2 to week 6, students would have the opportunity to come up with a design strategy during each class for their design project. After class, each team is required to complete the design of their projects based on the strategies identified in class. The quality and quantity of the discussions, feedbacks and presentations about each team's project would be evaluated and counted towards 30% of the final grade.

The week 7 class would be the final presentation for everyone to submit their final documentation and present to the class of their project deliverables. This overall course project accounts for 60% of the final grade.

The 100 point grading scale for this course is in the table below. Other grading considerations are in line with the official school grading policies.

100 Point Grading Scale	Letter Grade Equivalent
100-104	A+
96-100	A
90-95	A-
85-89	B+
80-84	B
76-79	B-
70-75	C+
65-69	C
60-64	C-
55-59	D
0-58	F

Course Reading Material

- Week 1:
    - Mandatory:
        1. Tarlov AR. (1999) Public policy frameworks for improving population health. Ann N Y Acad Sci. 896:281-93. https://pubmed.ncbi.nlm.nih.gov/10681904.

2. International WELL Building Institute. (2021). WELL Building Standard v2. Accessed on December 23, 2021. https://v2.wellcertified.com/wellv2/en/overview
3. International WELL Building Institute. (2021). WELL v2 country briefs. Accessed on December 23, 2021. https://www.wellcertified.com/certification/v2-pilot/country-briefs

- Optional:

1. World Green Building Council Report. (2014). Health, Wellbeing and Productivity in Offices. Accessed on December 23, 2021. https://www.glass.org/sites/default/files/2020-09/worldgbc__health_wellbeing__productivity_short_report.pdf
2. Institute for Health Metrics and Evaluation. Global Burden of Disease (GBD). Accessed on December 27, 2022. https://www.healthdata.org/gbd/2019#:~:text=The%20Global%20Burden%20of%20Disease,be%20improved%20and%20disparities%20eliminated.
3. GBD 2019 Risk Factors Collaborators. x(2020) Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet. 396: 1223 - 1249. https://doi.org/10.1016/S0140-6736(20)30752-2.
4. Klepeis NE, Nelson WC, Ott WR, et al. (2001) The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. Journal of exposure analysis and environmental epidemiology. 11(3):231-252. https://www.nature.com/articles/7500165.
5. EY. (2021) The future of sustainability reporting standards: the policy evolution and the actions companies can take today. Accessed on December 23, 2021. https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/sustainability/ey-the-future-of-sustainability-reporting-standards-june-2021.pdf
6. Loftness, V., Hartkopf V., Grtekin B. et al. Building Investment Decision Support: Cost-benefit tool to promote high performance components, flexible infrastructures and systems integration for sustainable commercial buildings and productive organizations. Carnegie Mellon University. Accessed on December 23, 2021. https://www.brikbase.org/sites/default/files/aiab080586_01.pdf
7. Lister, K. (2014). What's Good for People, Moving from Wellness to Well-Being. Knoll Workplace Research. Accessed on December 23, 2021. https://www.knoll.com/document/1353003180652/Well_Being_wp.pdf

- Week 2:
    - Mandatory:
        1. Yu W, Ye T, Zhang Y, Xu R, et al. (2023) Global estimates of daily ambient fine particulate matter concentrations and unequal spatiotemporal distribution of population exposure: a machine learning modelling study. The Lancet Planetary Health, 7(3). https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(23)00008-6/fulltext.
        2. International WELL Building Institute. (2021). WELL Building Standard v2. Accessed on December 23, 2021. https://v2.wellcertified.com/wellv2/en/overview (Air, Water, Thermal, Sound, and Material)
        3. Wang Z, de Dear R, Luo M, Lin B, He Y, Ghahramani A, Zhu Y, (2018) Individual difference in thermal comfort: A literature review, Building and Environment, https://www.sciencedirect.com/science/article/abs/pii/S0360132318302518
        4. Understanding at least one of the six material safety programs: Healthy Product Declaration Program, Declare, UL GREENGUARD, Cradle to Cradle, and Level by BIFMA.
        5. Bernstein, E.S. and Turban, S. (2018). The impact of the 'open' workspace on human collaboration. Phil. Trans. R. Soc. B3732017023920170239. https://doi.org/10.1098/rstb.2017.0239.
    - Optional:
        1. Landrigan PJ. Air pollution and health. The Lancet Public Health. 2017;2(1). doi:10.1016/s2468-2667(16)30023-8
        2. Burkart, K.G., Brauer, M., Aravkin, A.Y., et al. (2021) Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. Lancet 2021; 398: 685–97. https://www.thelancet.com/action/showPdf?pii=S0140-6736%2821%2901700-1
        3. Clasen T, Pruss-Ustun A, Mathers CD, Cumming O, Cairncross S, Colford JM Jr. Estimating the impact of unsafe water, sanitation and hygiene on the global burden of disease: evolving and alternative methods. Trop Med Int Health. 2014 Aug;19(8):884-93. https://onlinelibrary.wiley.com/doi/full/10.1111/tmi.12330.
        4. Health effects caused by noise: Evidence in the literature from the past 25 years. Ising, H and Kruppa, B. 22, Berlin : s.n., 2004, Noise & Health, Vol. 6, pp. 5-13.

http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2004;volume=6;issue=22;spage=5;epage=13;aulast=Ising.

5. S. P. Banbury and D. C. Berry, “Office noise and employee concentration: identifying causes of disruption and potential improvements,” Ergonomics, vol. 48, no. 1, pp. 25–37, Jan. 2005, https://doi.org/10.1080/00140130412331311390.
6. Berto, R. (2005) Exposure to restorative environments helps restore attentional capacity. J. Environ. Psychol., 25(3), 249–259. https://doi.org/10.1016/j.jenvp.2005.07.001.
7. Brown, D. K., Barton, J. L., and Gladwell, V. F. (2013) Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress. Environ. Sci. Technol. 47(11) 2013: 5562–5569. https://doi.org/10.1021/es305019p.
8. Jamrozik, A., Clements, N., Hasan, S.S. et al. (2019) Access to daylight and view in an office improves cognitive performance and satisfaction and reduces eyestrain: A controlled crossover study. Building and Environment, 165, 2019: 106379, https://doi.org/10.1016/j.buildenv.2019.106379.
9. Cameron A., Burns, P., Garner, et al. (2019) Making Sense of Multi-Sensory Environments: A Scoping Review, International Journal of Disability, Development and Education, https://doi.org/10.1080/1034912X.2019.1634247.

- Week 3:
    - Mandatory:
        1. Moore-Ede, Martin, et al. “Lights Should Support Circadian Rhythms: Evidence-Based Scientific Consensus.” Frontiers, Frontiers, 20 Sept. 2023, www.frontiersin.org/articles/10.3389/fphot.2023.1272934/full.
        2. International WELL Building Institute. (2021). WELL Building Standard v2. Accessed on December 23, 2021. https://v2.wellcertified.com/en/wellv2/light.
    - Optional:
        1. Karlen, Mark, et al. Lighting Design Basics, John Wiley & Sons, Incorporated, 2012. ProQuest Ebook Central, https://ebookcentral-proquest-com.proxy.library.upenn.edu/lib/upenn-ebooks/detail.action?docID=822035.
        2. Lucas RJ, Peirson SN, Berson DM, Brown TM, Cooper HM, Czeisler CA, Figueiro MG, Gamlin PD, Lockley SW, O'Hagan JB, Price LL, Provencio I, Skene DJ, Brainard GC. Measuring and using light in the melanopsin age. Trends Neurosci. 2014 Jan;37(1):1-9. doi: 10.1016/j.tins.2013.10.004. Epub 2013 Nov 25. PMID: 24287308;

PMCID: PMC4699304.

- Week 4:
    - Mandatory:
        1. Karlen, Mark, et al. Lighting Design Basics, John Wiley & Sons, Incorporated, 2012. ProQuest Ebook Central, https://ebookcentral-proquest-com.proxy.library.upenn.edu/lib/upenn-ebooks/detail.action?docID=822035.
        2. International WELL Building Institute. (2021). WELL Building Standard v2. Accessed on December 23, 2021. https://v2.wellcertified.com/en/wellv2/light.
    - Optional:
        1. Carolyn B. Swope, Shengliang Rong, Carolina Campanella, Regina Vaicekonyte, Andrew JK Phillips, Sean W Cain & Elise M McGlashan (2023) Factors associated with variability in the melatonin suppression response to light: A narrative review, Chronobiology International, 40:4, 542-556, DOI: 10.1080/07420528.2023.2188091.
        2. Brandi, Ulrike. Lighting Design : Principles, Implementation, Case Studies, Walter de Gruyter GmbH, 2006. ProQuest Ebook Central, https://ebookcentral-proquest-com.proxy.library.upenn.edu/lib/upenn-ebooks/detail.action?docID=3045442.
- Week 5:
    - Mandatory:
        1. Terrapin. 14 Patterns of Biophilic Design. Accessed on January 29, 2024. https://www.terrapinbrightgreen.com/reports/14-patterns/.
        2. Putrino, D., Ripp, J., Herrera, J.E.., et al. (2020) Multisensory, Nature-Inspired Recharge Rooms Yield Short-Term Reductions in Perceived Stress Among Frontline Healthcare Workers. Frontiers in Psychology, 11, 2020: 3213. https://www.frontiersin.org/article/10.3389/fpsyg.2020.560833.
    - Optional:
        1. Kellert, S. R, Heerwagen, J., & Mador, M. (2008). Biophilic design : the theory, science, and practice of bringing buildings to life. Hoboken, N.J.: Wiley. (Chapter 8 "Where Windows Become Doors")
        2. International Living Future Institute. Biophilic Design Initiative. Accessed on January 29, 2024. https://living-future.org/biophilic-design/.
- Week 6:
    - Optional:
        1. Corburn, Jason. “City Planning as Preventive Medicine.” Preventive Medicine 77 (August 2015): 48–51. https://doi.org/10.1016/j.ypmed.2015.04.022.

2. (2021). WELL Building Standard v2. Accessed on December 23, 2021. https://v2.wellcertified.com/wellv2/en/overview (only read Nourishment, Movement and Community).
3. City of North Vancouver. (2015) Active Design Guidelines. https://www.cnv.org/-/media/City-of-North-Vancouver/Documents/Active-Design/Active-Design-Guidelines.pdf.
4. Nancy D. Berkman, Terry C. Davis & Lauren McCormack (2010) Health Literacy: What Is It?, Journal of Health Communication, 15:sup2, 9-19, https://doi.org/10.1080/10810730.2010.499985.
5. Daniel Kahneman (2011). Thinking, Fast and Slow. Macmillan.
6. Thaler, Richard, and Cass Sunstein (2008). Nudge: Improving Decisions About Health, Wealth, and Happiness. Penguin Books.
7. Michael Lewis (2016). The Undoing Project. W. W. Norton & Company.
8. Gladwell, Malcolm (2007). Blink. Back Bay Books.