Massachusetts Institute of Technology
4.411J/EC.713J D-Lab Schools: Building Technology Laboratory

Pandemic-resilient, thermally comfortable K-12 schools in your neighborhood

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Units:  2-4-6 (Institute Lab)

Prerequisites:  8.01, 18.01

Schedule:  Lecture  Wednesday, 9:30-11:00 a.m.
Lab  Monday 2:00-5:00 p.m.
Office hours to be announced and on request
Lectures and labs will be held synchronously and recorded and will be supplemented with substantial asynchronous material. Lectures and labs will typically include discussion of previously assigned readings or investigations. Access to space for model construction for those on campus will be considered.

**Description**

This year's course focus will be the design of a “high-performance school” located where you live. Perhaps this is a school in your neighborhood or one you may have attended in your childhood. The goal is to improve thermal comfort of the students and teachers and provide a healthy learning environment while attempting to provide necessary energy from on-site, renewable sources. The focus on the physical environment for education builds on previous work within the Building Technology Program and the D-Lab Schools: Building Technology Lab course for schools in Cambodia, Haiti, Nepal, Pakistan, Sierra Leone, Singapore and South Africa.

The design program is a primary-secondary school serving grades three through eight, developed by the town or city of your choice to accommodate a deficiency in the school district’s learning objectives. The building is three levels with a total of twenty-four classrooms. The total area is 1324.5 square meters and the building is 12 meters tall. This school is intended to serve as a model for other schools in the area. It is also intended to demonstrate effective ways of responding to COVID-19 without negatively impacting the educational experience or performance of the students. The school has a mission of emphasizing outdoor learning spaces as a means to improve learning outcomes and mitigate the impacts of the Corona virus.

Students taking this course will be asked to modify an existing floor plan that incorporates an outdoor classroom or rooms. Any idea is encouraged for this project. Ideas may involve adjusting school schedules to accommodate the most optimal seasonal conditions. Students may find the need to design roof systems that absorb sunlight, collect water, and provide shade. Other students may focus on wall systems that, in addition to supporting roof structures, direct wind, remove humidity, lower air temperatures, and absorb heat at the most optimal times of the year. Students taking this course will be required to complete a series of weekly modules that will allow them to develop the skills necessary to design their local high-performance school.

The course is set up as a series of short studies and projects based on observation, experiments, simulation and design. Necessary in-class instruction in simulation software will be supplemented by online tutorials. Results of these investigations will be shared in class sessions, described in three submitted reports and summarized in a final presentation.

Software we anticipate using includes Rhino and the associated Grasshopper visual scripting program, which will allow us to perform climate, thermal comfort, airflow analyses and energy analyses within a design framework that easily obtains necessary geometrical information from a CAD model. We may also employ stand-alone software for structural design and pollutant transport.
Course objectives:

- Develop an understanding of culture, education systems, climate and construction methods and materials in the country and local region of the school under consideration.
- Develop an ability to analyze climate, its impact on the thermal comfort of school occupants and its influence on building design.
- Through experiments, application of engineering fundamentals and simulations, learn to quantify key aspects of building performance, including daylighting, moderation of indoor temperature, natural ventilation, pollutant concentration and structural integrity and efficiency.
- Develop an ability to propose and assess low-energy buildings that provide a healthy indoor environment.
- Improve written and oral communication skills, including an ability to present design concepts and building performance to a non-technical audience.

Evaluation criteria:

The course grade will be based on participation in class and lab reports. Weekly assignments will require work that will be incorporated into the reports and may be presented orally in labs for discussion and feedback but will not be graded. Participation is crucial to the success of the course. Attendance in lab and lecture will be noted.

Given that the class will be taught remotely and the barriers that time zones and distance create for group work, it is anticipated that students will work as individuals and not small teams. Alternatives will be considered by the instructor, TA and class participants. There will be ample time for group sharing of individual work.

Course work will be weighted as follows:

- report #1: 25%
- report #2: 25%
- report #3 and final presentation: 25%
- Attendance and participation: 25%

There is no final exam in this course and there will be no quizzes. Reports should be submitted on time and will be evaluated and returned within one week of submittal. Schedule adjustments will be considered as necessary to significant academic deadlines, the impact of local weather on experimental work, availability of computing infrastructure, and personal well-being.

An MIT 12-unit course, including this one, should require on average no more than 12 hours of work per week, in and out of class sessions. If your work load consistently exceeds this amount, please cut back and/or inform the instructor.
Reading List:

Books for checkout or purchase –

https://mitpress.mit.edu/books/lifelong-kindergarten

https://press.princeton.edu/books/hardcover/9780691170039/modern-architecture-and-climate

https://www.bloomsbury.com/uk/the-design-of-childhood-9781632866370/

Articles and Research Papers–

**Impact of Temperature and Air Quality on Learning Outcomes:**


**Diversity, Collaboration, and K-12 learning:**

https://www.k12blueprint.com/toolkits/active-learning-spaces

AIA Guide to Safer Schools.

Nice White Parents (New York Times/Serial podcast)
Schoolyards/Playgrounds/Landscapes:


National COVID-19 Outdoor Learning Initiative.
https://www.greenschoolyards.org/covid-19-overview-outdoor-learning

Maintenance and Building quality for K-12 Schools:

National Center for Education Sciences. Changes in America’s Public School Facilities: From School Year 1998-99 to School Year 2012-13

How Crumbling School Facilities Perpetuate Inequality
https://journals.sagepub.com/doi/full/10.1177/0031721719846885

References (no required textbooks) –


Reinhart, Christoph F. Daylighting Handbook I: Fundamentals, Designing with the Sun 2014 ISBN 9780692203637

Reinhart, Christoph F. Daylighting Handbook II: Daylight Simulations | Dynamic Facades 2018 ISBN 9780578407098
## Tentative Schedule

<table>
<thead>
<tr>
<th>Type</th>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>Lecture</td>
<td>9/2</td>
<td>Course overview, impact of the indoor environment on student performance, tension between comfort, energy use and indoor air quality.</td>
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<td></td>
<td>9/7</td>
<td>Labor Day holiday</td>
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<tr>
<td>Lecture</td>
<td>9/9</td>
<td>Thermal comfort and climate fundamentals</td>
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<tr>
<td>Lab</td>
<td>9/14</td>
<td>School assessment. Outdoor and indoor thermal comfort metrics; prediction of satisfactory classroom conditions</td>
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<tr>
<td>Lecture</td>
<td>9/16</td>
<td>Climate investigation, indoor and outdoor thermal comfort with Ladybug</td>
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<tr>
<td>Lab</td>
<td>9/21</td>
<td>Present first week of comfort log; LB climate assessment; In lab design exercise: Sketch designs of indoor and outdoor spaces to provide thermal comfort: passive and active alternatives</td>
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<tr>
<td>Lecture</td>
<td>9/23</td>
<td>Thermal fundamentals: steady-state heat transfer, properties of insulation materials and windows.</td>
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<td>Lab</td>
<td>9/28</td>
<td>Design and construction of passive solar indoor or outdoor space.</td>
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<tr>
<td>Lecture</td>
<td>9/30</td>
<td>Thermal transients, first-order estimates of transient temperatures.</td>
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<td>10/2</td>
<td><strong>Add Date</strong></td>
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<tr>
<td>Lab</td>
<td>10/5</td>
<td>Feedback on thermal test. Lighting fundamentals and indoor/outdoor measurements.</td>
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<tr>
<td>Lecture</td>
<td>10/7</td>
<td>Daylighting simulation; Comparison of measurements with simulation.</td>
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<td>10/12</td>
<td><strong>Columbus Day</strong></td>
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<tr>
<td>Lab</td>
<td>10/13</td>
<td>Monday class schedule for Tuesday, October 15. Thermal test results. Fundamentals of natural ventilation. <strong>Report #1 due.</strong></td>
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<tr>
<td>Lecture</td>
<td>10/14</td>
<td>Buoyancy- and wind-driven airflows; airflow mass and energy balances;</td>
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<tr>
<td>Lab</td>
<td>10/19</td>
<td>indoor and outdoor airflow simulations using analytic mass-energy balances and nodal airflow models</td>
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<tr>
<td>Lecture</td>
<td>10/21</td>
<td>particle and droplet emissions, other indoor pollutants, ventilation for indoor air quality [Leon Glicksman]</td>
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<tr>
<td>Lab</td>
<td>10/26</td>
<td>Structural, thermal and lighting design of outdoor learning pavilion [John Ochsendorf]</td>
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<tr>
<td>Date</td>
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<tr>
<td>10/28</td>
<td>Lecture: Estimating droplet and aerosol dispersion; introduction to computational fluid dynamics (CFD)</td>
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<tr>
<td>11/2</td>
<td>Lab: CFD or nodal simulation of particle transport; Ventilation systems; low-energy cooling strategies for increased airflow [Forrest Meggers]</td>
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<td>11/4</td>
<td>Lecture: Dehumidification with desiccants and membranes.</td>
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<td>11/9</td>
<td>Lab: Roof-top energy systems, including photovoltaic electricity, solar-thermal systems and radiative cooling. <strong>Report #2 due.</strong></td>
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<td>11/11</td>
<td><strong>Veteran’s Day holiday</strong></td>
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<td>11/16</td>
<td>Lab: Whole-building energy balances and annual thermal performance using Rhino and Honeybee</td>
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<td>11/18</td>
<td>Lecture: Design of pandemic-resilient classroom block. <strong>Drop Date;</strong></td>
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<td>11/21-29</td>
<td><strong>Thanksgiving vacation</strong></td>
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<tr>
<td>11/30</td>
<td>Lab: Design testing. Performance assessment of classroom block, including energy demand, airflow and thermal comfort</td>
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<td>12/2</td>
<td>Lecture: Resolving conflicts between local, neighborhood and global energy use and pollutant concentrations and transport</td>
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<td>12/4</td>
<td>D-Lab: D-Lab Fall Showcase</td>
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<td>12/7</td>
<td>Lab: Thermal comfort data analysis: relating thermal sensation to comfort metrics</td>
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<tr>
<td>12/9</td>
<td>Lecture: <strong>Last day of classes. Final presentations. Report #3 due.</strong></td>
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**Cover Images:**


Canvas

This course has a Canvas site, where homework assignments and instructions will be posted and where lab reports can be submitted electronically.

Academic integrity + honesty

Academic integrity is a serious issue. Data sources must include attribution. Lab reports must reflect the thoughts and efforts of identified students. Please familiarize yourself with MIT’s Academic Integrity expectations at http://web.mit.edu/academicintegrity/.

Software

At appropriate times in the course you will be asked to install many the following software, for which (near) current download links are provided.

Rhino 6.0  https://www.rhino3d.com/download – we need Windows version to work with grasshopper, which is included in the download. There is a free 30-day evaluation version; longer-term usage requires a $195 educational license

Ladybug and Honeybee (and other insects!)  https://www.ladybug.tools/index.html – the insects provide grasshopper plug-ins for analysis and visualization of climate, thermal comfort, building energy use and airflow

CoolVent  http://coolvent.mit.edu/download/ – airflow and thermal analysis

CONTAM  https://www.nist.gov/services-resources/software/contam – nodal airflow analysis and pollutant transport

DIVA for Rhino  https://www.solemma.com/Diva.html – includes daylightng and building energy analysis and visualization

scSTREAM – computational fluid dynamics program. Download and installation instructions will be provided at the appropriate time.

CBE thermal comfort tool  http://comfort.cbe.berkeley.edu – an online program developed by the Center for the Built Environment at UC Berkeley that locates specified environmental and occupant conditions within a region of acceptable thermal parameters

Climate Consultant  http://www.energy-design-tools.aud.ucla.edu – a freely downloadable tool that runs under Windows or Mac OS and provides a relatively comprehensive set of non-customizable graphical presentations of data from standard weather files. We prefer Ladybug and the CBE thermal comfort tool but acknowledge that Climate Consultant is easy to use for standard climate information.