(Board 100: Work in Progress): Creating Human-centered Building Design Curriculum: Understanding the Health Impacts of Active, Collaborative Learning - An Analysis Using CFD and GD-BIM in an Existing Classroom with Discussion Tables

Mr. Simon Zhang, University of Illinois Urbana-Champaign

Hello there! I'm a fourth-year PhD student at the University of Illinois Urbana-Champaign, specializing in Agricultural and Biological Engineering. My research dives into the critical realm of air quality and human health, notably relevant in the context of the ongoing COVID era.

Besides the lab research, I have been teaching multiple courses, most noticeably, a freshmen-level CAD class in Industrial and Enterprise System Engineering since my sophomore year (yes! eight years in the same class).

I enjoy teaching wholeheartedly; I want to use my technical expertise in air quality and human health to help reshape the post-pandemic learning environment, combining advantageous collaborative and active learning with a safe and healthy environment.

Looking forward to exchanging ideas at the conference!

Dr. Molly H Goldstein, University of Illinois Urbana-Champaign

Dr. Molly H. Goldstein is a Teaching Assistant Professor and Product Design Lab Director in Industrial and Enterprise Systems Engineering at the Grainger College at the University of Illinois. She is also courtesy faculty in Mechanical Science and Engineering, Curriculum & Instruction (College of Education) and Industrial Design (School of Fine and Applied Arts). Dr. Goldstein's research focuses on student designers through the study of their design actions and thinking.

Mahdi Azizi, University of Illinois Urbana-Champaign
Amir Malvandi, University of Illinois Urbana-Champaign

(WIP) Creating human-centered building design curriculum: Understanding Health Impacts of Active, Collaborative Learning - An Analysis Using CFD and GD-BIM in an Existing Classroom with Discussion Tables.

Introduction:
In this Work-In-Progress poster, we recognize the manifold advantages of discussion-based and team-oriented learning in contrast to traditional lecture-style formats. However, in light of the recent COVID-19 pandemic, heightened attention has been directed toward indoor air quality, particularly in confined spaces such as classrooms where extensive face-to-face interactions occur, perhaps discouraging team discourse. Conventional classroom designs, whether for discussions or lectures, were not originally conceived to consider and accommodate ample personal space. While there have been a few studies on airflow and airborne particle transmission in lecture-style settings, a noticeable gap exists in the analysis of discussion-based classroom configurations where closer interpersonal interactions are expected.

We aim to combine traditional parametric and emerging generative design techniques to inform and improve the physical environment for collaborative learning as a part of the human-centered design curriculum focused on occupant health in building design.

Our objective is to leverage AI-driven Generative Design to design improved learning environments that consider air quality as a crucial constraint. We intend to achieve this by utilizing Computational Fluid Dynamics (CFD) simulations within a heavily utilized discussion-based classroom. Subsequently, we aim to optimize the classroom layout, seating arrangements, and HVAC settings using Generative Design in Building Information Modeling (GD-BIM) methodologies to minimize the transmission of airborne disease particles.

Objectives:
Our objective is to demonstrate the workflow of rapid building design using GD-BIM and health risk using CFD by assessing the potential risk of student exposure to infection during collaborative interactions within a discussion-style classroom. We also aim to optimize the room layout to prioritize student health and safety while preserving the beneficial discussion-style learning using the GD-BIM.

Methods:

We conducted measurements inside a classroom featuring four large discussion tables and four collaborative tables equipped with a computer. To ensure accurate room dimensioning, we compared the measurement to the construction blueprints. The room is further characterized by a door, two window-mounted air-conditioning units, and eight windows.

Leveraging CAD software Autodesk Fusion and Revit, we meticulously constructed a detailed digital classroom model. Subsequently, we executed CFD simulations using Ansys Fluent for various scenarios, including cases with doors and windows open and closed, and variations in the operation of the air conditioning system. More importantly, these simulations also considered the presence of students' activities such as speaking, coughing, and sneezing.

Moreover, we employed Autodesk Revit GD-BIM to optimize the classroom's seating arrangement and HVAC layout. Finally, we repeated the CFD simulations and compared them with the existing room layout benchmark results to determine whether there were any improvements in air quality.

Preliminary Results:

Preliminary results suggest that this innovative integration of AI-driven Generative Design in Building Information Modeling (GD-BIM) with advanced Computational Fluid Dynamics (CFD) simulations carries significant implications for student health in the context of collaborative learning. This pioneering workflow not only promises to influence but also expedites the design of interior layouts conducive to collaborative learning, thereby enhancing the overall health and learning experience for students.

Data support:

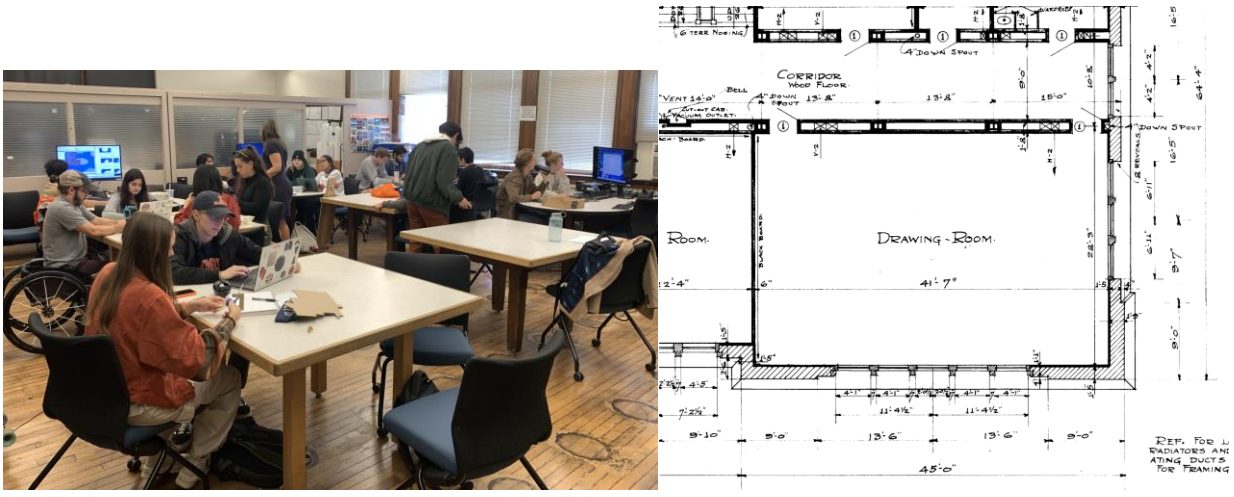

Figure 1 The heavily utilized discussion-based classroom and the building blueprint from the university archive.

We measured the room interior, including the location of the table and chairs, window size and location, window AC sizes and locations, and airspeed. We verified the measurements with the building blueprint from the archive.

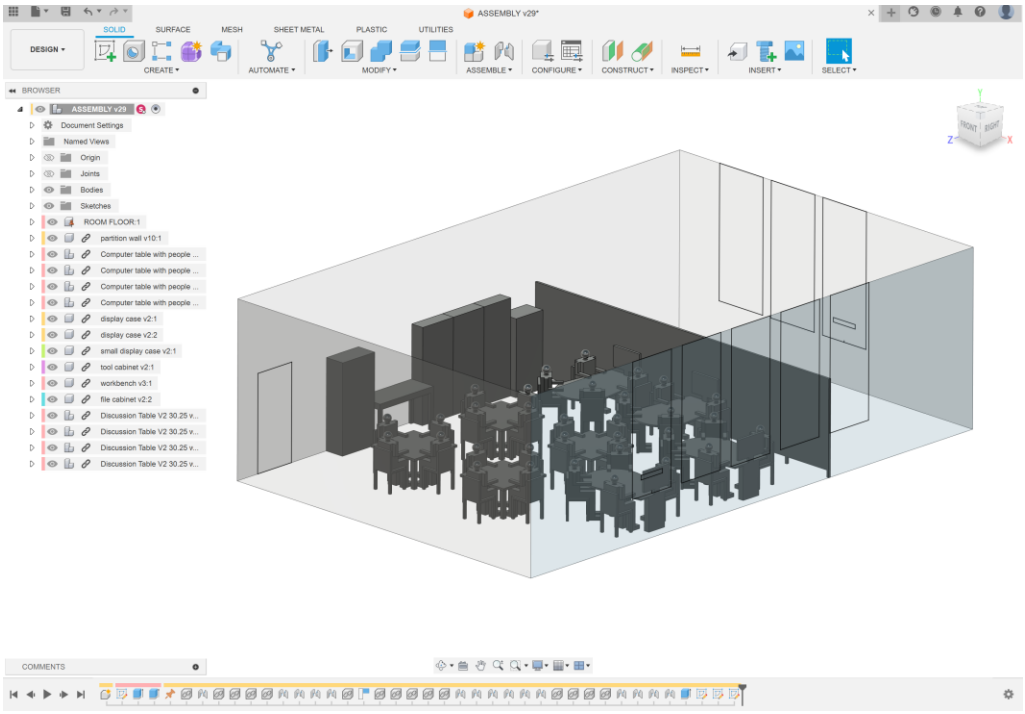

Figure 2 CAD model of the classroom in Autodesk Fusion

Based on the measurement and blueprint, we realistically constructed the room using Autodesk Fusion, including the walls, doors, windows, window ACs, partitioning walls, cabinets, and tables.

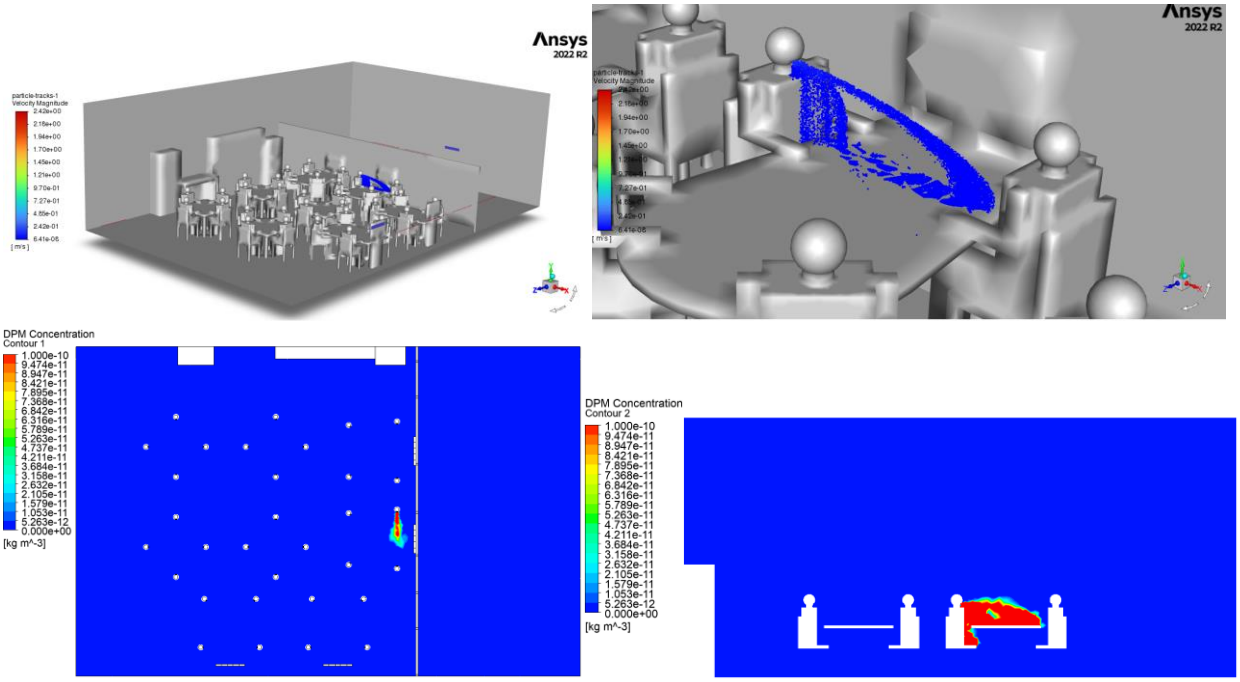

Figure 3 CFD simulation of one student talking without air conditioning, showing particles concentrated in the table in front of the students.

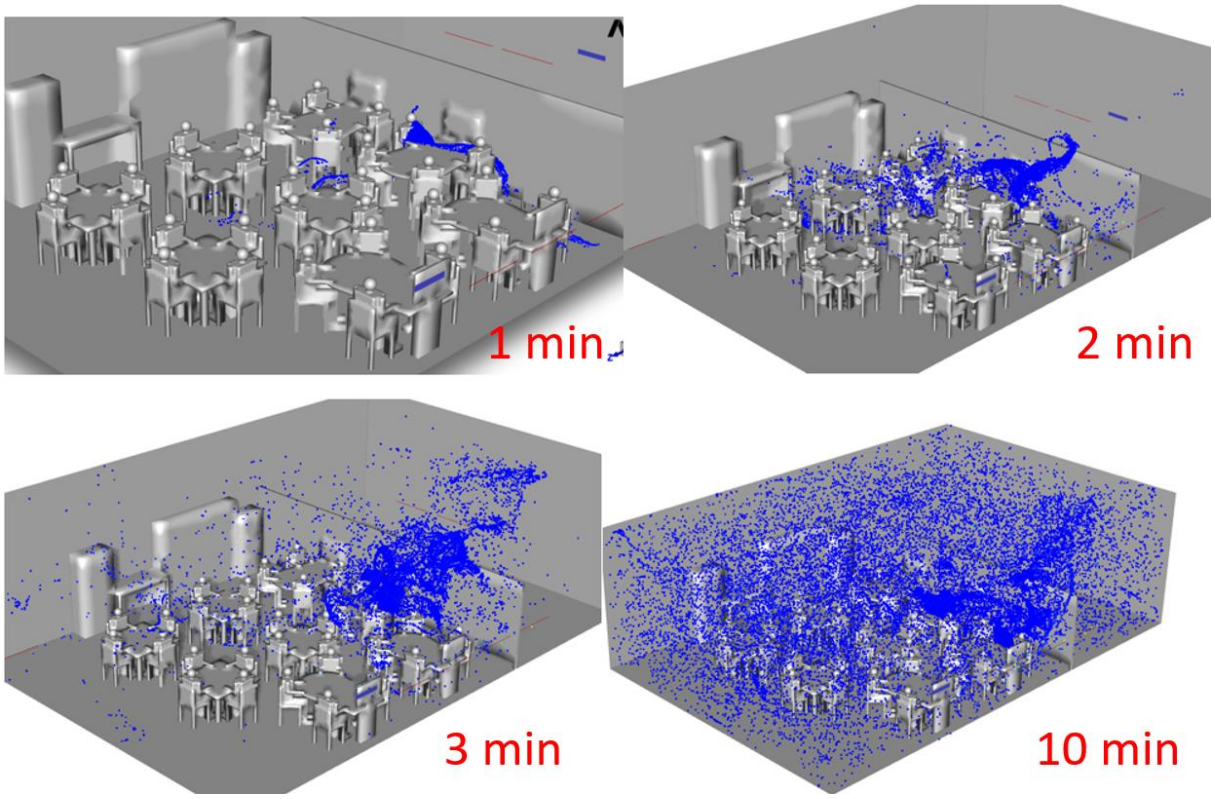

Figure 4 3D CFD simulation of particle transport inside the classroom in Ansys Fluent generated by a student continuously speaking with air conditioning as time progresses.

The introduction of ventilation indeed lowers the concentration at the location of particle generation (i.e., near the speaking student); however, the airflow will carry smaller particles around the room, leading to a potentially larger area for infection.

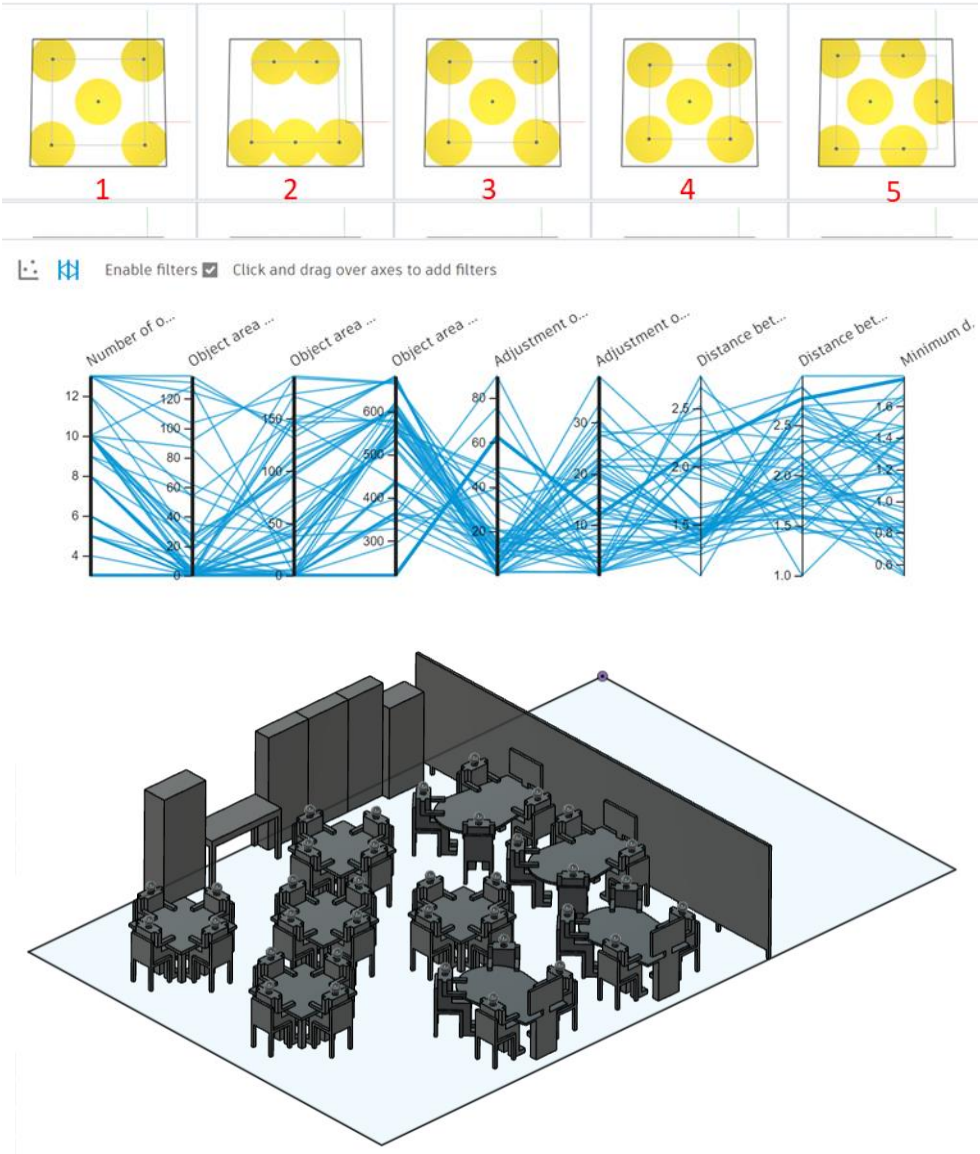

Figure 5 CAD modification according to GD-BIM in Autodesk Revit optimization result based on maximizing occupancy.

The GD-BIM in Autodesk Revit will generate numerous layouts in a matter of minutes according to user input parameters such as location, spacing, and distance from the window. The designer can then pick favorable designs more suited to realistic needs, the selected design then will be

automatically promoted into the modeling space. For example, design 1 puts the tables too far apart, some even close to the door exit path, and design 2 does not allow teachers easy access to the three tables towards the bottom.

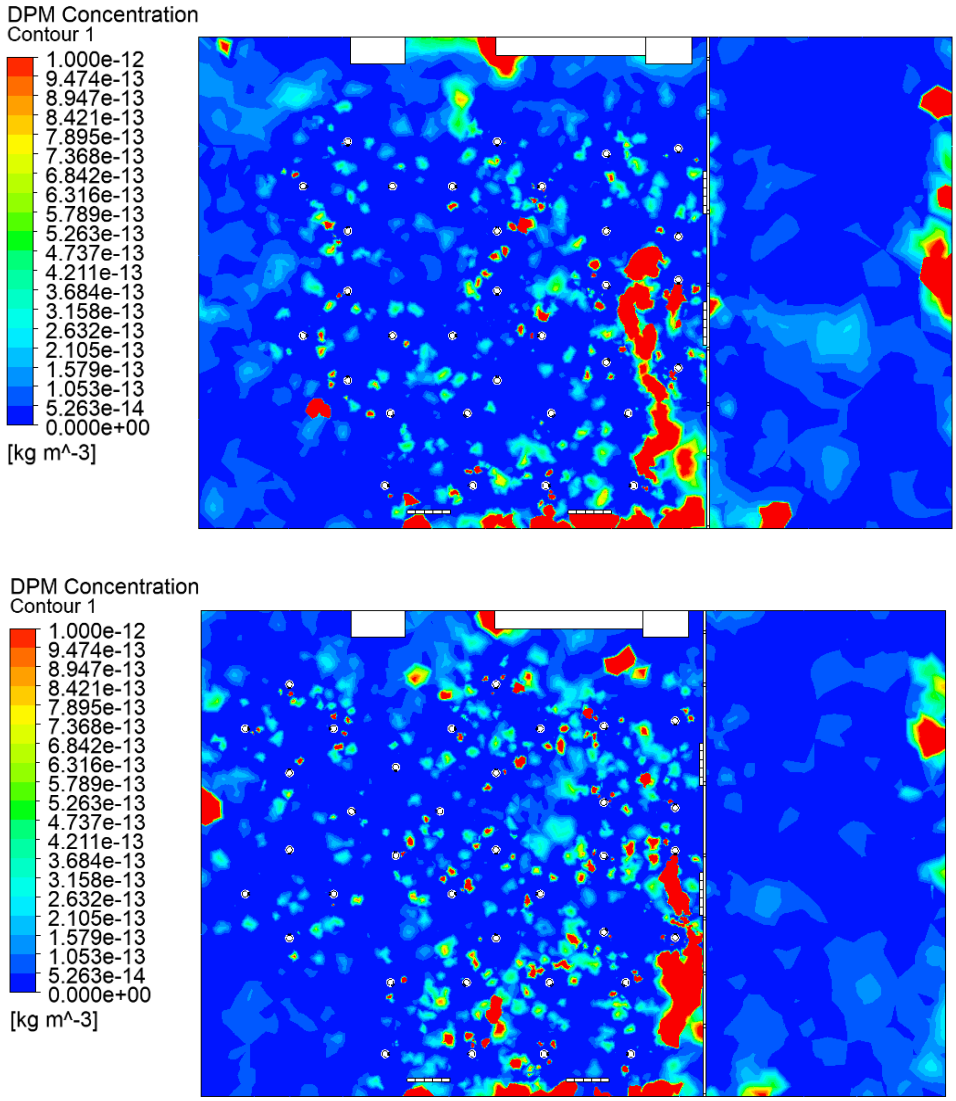

Figure 6 2D particle concentration results for different seating arrangements (top is the original, bottom is added seats) modified from GD-BIM under the same environmental conditions, showing the different layouts impact students' health conditions.

Results from CFD demonstrate particle concentration distribution in the room at a certain height level (in this case, at the mouth level, where breathing and infections occur), showing hotspots or

regions with higher particle concentration in red. The simulation can be used to evaluate different seating arrangements and improving HVAC system layouts.