CHANGING THE RELATIONSHIP OF FORM AND PERFORMANCE: THE CONCEPTUAL INTEGRATION OF QUANTITATIVE PERFORMANCE EVALUATIONS INTO DESIGN PEDAGOGY

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DEVELOPING SUSTAINABLE DESIGN PEDAGOGY

In Sustainable Environmental Design Teaching, Research and Practice Simos Yannas[1] identifies the need for a 'clearly laid out, continuously evolving approach that sees sustainable design as an integral part of architectural training from the outset'. Thus sustainable design is not an optional technical addendum, but a key ingredient in a new practice that needs to be fostered by a different approach to architectural education. According to Yannas this approach is defined by a holistic knowledge triangle, which might have 'different origins' and might well 'represent different forms of learning' than we know today. The first point on this knowledge triangle is indicated as the word pair 'Conceptual / Theoretical', which deals with 'Knowledge and understanding of how natural processes and the occupant's environmental design requirements translate into architectural design'. The second edge is 'Empirical /Experiential', which requires 'Data acquisition and systematic assessment of how things have worked in practice' and the third point is called 'Analytical / Comparative', which relates to 'Parametric studies as an essential component of the learning process as well as a means of informing sustainable environmental design'. Direct access to knowledge within the 'Analytical / Comparative' branch of the triangle is a new component to the architecture profession and to professional architectural education where environmental forces and controls were long taught by one instructor to a group of 80+ students separate from design studio instruction[2].

CASE STUDY #1: INTEGRATING DYNAMIC PERFORMANCE EVALUATION SOFTWARE TOOLS INTO CONCEPTUAL DESIGN

As noted by Passe, Demel (2012)[3] it is important and possible to integrate parametric performance evaluation tools into the design process. The 2011 ARS Berlin summer academy[4] started the design process with an analysis of the proportions of Berlin's urban street canyons, which then provided the basis for the evaluation of the new European Energy Forum (EUREF) master plan[5] with respect to its potential to provided minimum heat gain ins summer, while maintaining maximum harvest of daylight. Berlin's building typology developed about hundred and fifty years ago based on rapid economic growth due to industrialization and population growth. Most buildings had standardized floor plans with standardized openings. Façade ornamentations were applied from pattern books and best practices. Structural and spatial typology was developed out of economic necessity with minimum structural members where large wooden beams span from the façade to a central wall and to the back façade with lateral bracing provided by the stair core. Although this outcome might not have been planned from the outset, still today this strategy proves to be resilient to programmatic changes as it is able to accommodate multiple shades of Live - Work scenarios. The open floor plan with high ceilings is adapted well to changing needs and the strategy of programmatic adaptability thus well suited for sustainable standards.

Strategies for dynamic interaction, dynamic sequence of 'Light Sun Air'

Christoph Reinhart et all[6] introduced the concept of dynamic daylight performance metrics that captures the 'site-specific, dynamic interaction between a building, its occupants, and the surrounding climate on an annual basis' as an alternative design approach to mere static daylight factor calculations. The EUREF site in Berlin incorporated all of the above complexities therefore the Berlin summer academy team based its dynamic performance design strategy on this previous research work and introduced the student teams to DaySim[7] and Radiance[8], both non-commercial research tools. The goal was to achieve dynamic optimization. Design parameters included day-lighting harvesting to reduce artificial lighting during day lit times by investigating dynamic daylight factors. Analysis was first conducted to to maximize daylight use in winter and then to reduce the heat gain potential in summer. The design of a properly sized and oriented shading device for the summer significantly reduces the amount of solar gains, but the design has to balance this goal with the maximum use of daylight through a new metrics called daylight autonomy, which indicates daylight availability over the course of a year. The ideal result would be an evaluation of the overall strategy, occupancy levels, behavior and activities, as well as seasonal optimization of light transmitting surfaces for summer and winter to balance light transmission, heat gain and heat loss.

Additional challenges were introduced with seasonal passive solar strategies in winter and seasonal natural ventilation strategies in summer leading to operable envelope elements and a time-based usage of buildings. Utilizing a variety of software tools (the mentioned Radiance, Daysim get integrated into the commercial Autodesk Revit, Vasari and Ecotect as well as Rhinoceros, Grasshopper, Diva)[9] a specific workflow was developed, which started with a concept for a window or light transmitting surface for a typical space condition in the winter, when little light is available (Figure 1).

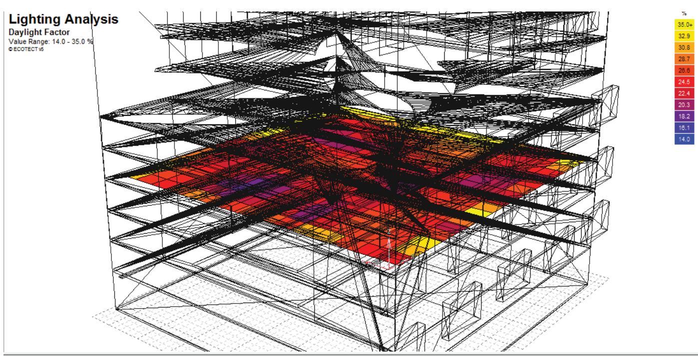

Figure 1. Daylight analysis for one floor level in Rhinoceros / Autodesk Ecotect to understand how a 3 dimensionally distorted courtyard enriches the daylight uniformity of internal spaces (Suncica Jasarovic, ARCH 490, Spring 2012).

CASE STUDY #2: SUSTAINABLE DESIGN AS STUDENT PERFORMANCE CRITERIA

In order to address the urgent challenge in the profession to enhance sustainable design, the ISU graduate studio ARCH 601 started in 2010 and requests the integration of design strategies that explore the relationship between buildings and environmental forces to produce projects that were efficient and non-wasteful with energy, water, material and other resources. This goal leads to a thorough design study of the impact of solar energy and wind patterns on building materials, passive and active systems and envelope strategies, spatial quality and form making. Decisions are validated quantitatively through energy modeling and performance simulation[10].

The analysis phase, which included required readings[11] and topical seminar discussions led to programmatic proposals for the combination of Living, Working and Learning to achieve a mixed-use development, which would incorporate varied occupancy schedules, comfort requirement and internal loads. The urban design phase was then followed by a process of detailing structure, space, and enclosures. Student teams specified thermal gaining, blocking or retaining envelope surfaces, how a window admits light and how a room is entered. All of these design specifics are determined by the way the threshold between inside and outside is conceived and constructed. How light falls into a space, through openings in walls, ceilings and across surfaces is determined by material choices and methods of assembly. The architectural projects came alive during the process of detailing and construction documentation. Physical detail models which test conceptual ideas were an integral part of the working process as were hand drawing, diagrams, models and simulations.

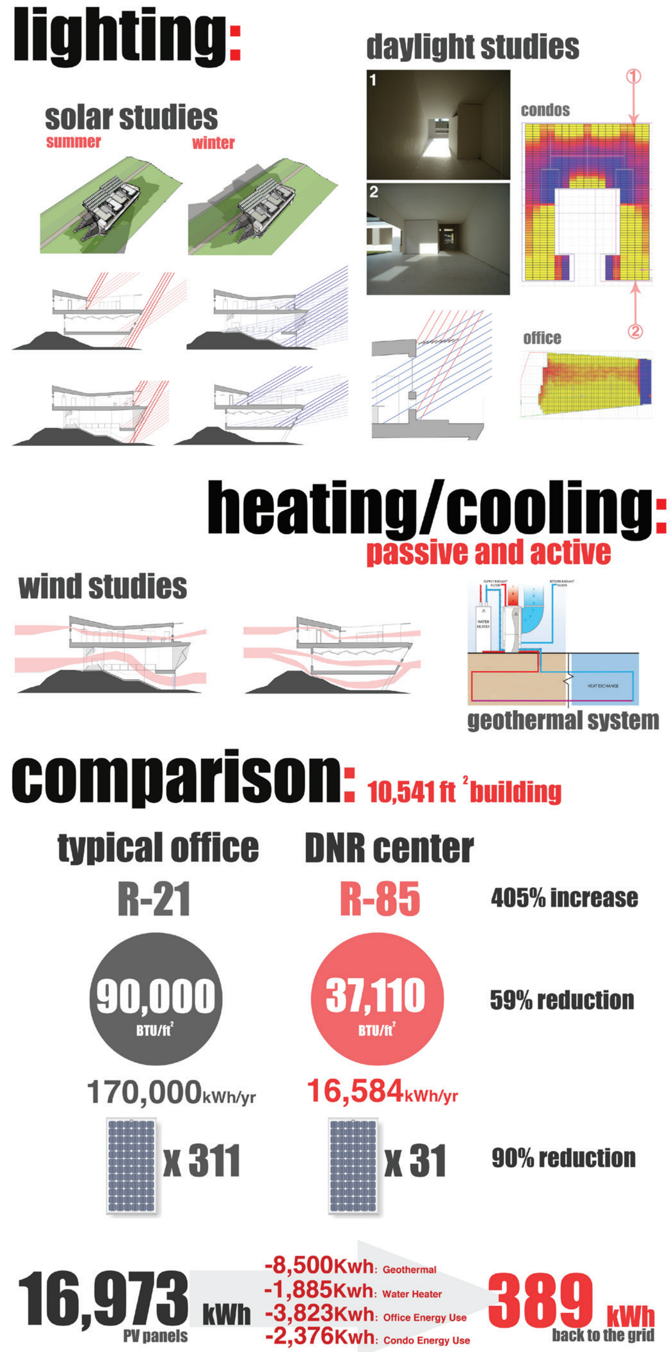

Figure 2. Energy Analysis presentation board with focus on daylighting studies, ventilation strategies and overall energy consumption (Nathan Scott, Adam Ninnemann, Michael Thole)

Outcomes and Objectives

The aim of the studio was to develop architectural design projects of manageable scale that explore the relationships among architecture and cultural landscapes and biological issues.

Team work was required and an emphasis placed on a regional site in Iowa, and its socio-economic conditions. These conditions are representative of similar situations throughout the State of Iowa, the Midwest and the US on the whole mirroring the development of the US American Society in its global context. The projects stress interdisciplinary research, engagement with local stakeholders and contemporary phenomena. Participants were requested to refine a building program based on site research, precedent analysis and to transfer it into feasible proposal.

Thus intensive engagement with a wide range of issues was expected at every stage of the project in order to critically think through an urban response to the challenge of sustainable and net zero energy building design.

Site Sections

The 2011 studio addressed the Live-Work-Learn program along the SE 14th Street Corridor in Des Moines, Iowa. This corridor had been identified by the City of Des Moines as a potential site for mixed use development and urban densification[12]. The studio teams were challenged to develop mixed use projects for this area as alternatives to the classic US x urban pattern of the automobile strip. In order to understand the site conditions each student documented their site analysis in a section that cut through 14th Street, one potential building site, and the opposite side of the corridor. The section was used as a graphic armature for identifying and illustrating important physical thresholds. For example, topographic changes (subtle or abrupt) are meaningful in relationship to pedestrian and vehicular circulation, solar access, and air movement. It was also important to notice changes in occupation and activity. Each site potentially reveals and identifies an infinite number of thresholds, and the selection and focus constitutes a personal analysis of the site. Each site is also thus considered as a 4-dimensional phenomenon, which includes time and microclimate. Solar patterns and wind are dynamic and in constant flux.

Schematic Design Development

In order to design a solid scheme for a project, which should use only the amount of energy, which is can produce on its site, it is necessary to gain thorough understanding of how spatial and programmatic design concepts relate to energy performance. While there are obviously some rules and best practices related to the physics of our environment, responses in the built world are varied. Precedent case studies opened up the diverse field of approaches to the integration of energy performance prediction into the design concept and studio participants gained the ability to critically evaluate the success of a case study project. The following topics where considered important:

•Building orientation and relationship to solar path over the course of year and seasons.
•Building program and circulation.
•Spatial concept and building envelope.
•Management of thermal environmental conditioning (heating/cooling), air quality and ventilation
•Integration of active and passive systems
•The various renewable energy systems
•Integration of daylighting strategies
•The water related building and site systems
•The vegetative environment
•Site related strategies

The outcome of these studies became a joint catalogue of potential strategies which promised to achieve a net zero energy performance for the LIVE WORK LEARN project along the SE 14th Street Corridor.

The final architectural design concepts manifested themselves in the way the building were constructed and detailed. Architectural elements were separated, layered or joining according to the intended spatial and formal composition AND according to technical necessities to achieve a functional whole. This conceptual notion got elevated to a new level of complexity when energy efficiency were implemented into the actual construction of a building. The projects had to answer, how heat retention and airtight envelopes, high performance windows and new innovative kinetic façade elements could gain aesthetic and conceptual value. Various drawing tools were used to visualize the outcome of a critical discourse how to conceptualize the effect and influence, which the need to design more airtight buildings with high R-values and high performance windows has on the appearance and aesthetic design decisions.

Therefore one large scale building section (and the respective elevation) was developed at ½ inch to the foot scale following the path of the sun and air in summer and winter leading from the south through the space and back on the north of the building to understand the energy flow path.

SIMULATION TOOLS

Since the late 1970s, simulations based on calculating and visualizing energy and mass flow processes in buildings have been undertaken in the building design team, but mainly remained in the realm of the engineering team members as they were time consuming and demanded a fairly detailed understanding of mathematics and physics. Architects usually remained in the realm of 'rules of thumb' till very recently. Since the mid 1990s it started to become possible to simulate and visualize buildings structural and energy performance behavior AND visualize this behavior in multiple iterations (Figure 3).

Slowly these new simulation tools are becoming more accessible and affordable and are making their way into the professional architecture education. While for many decades abstraction guided architectural thought, before three dimensional renderings provided photorealistic representation of a visual- spatial futures, these new tools can now visualize what previously remained invisible, namely

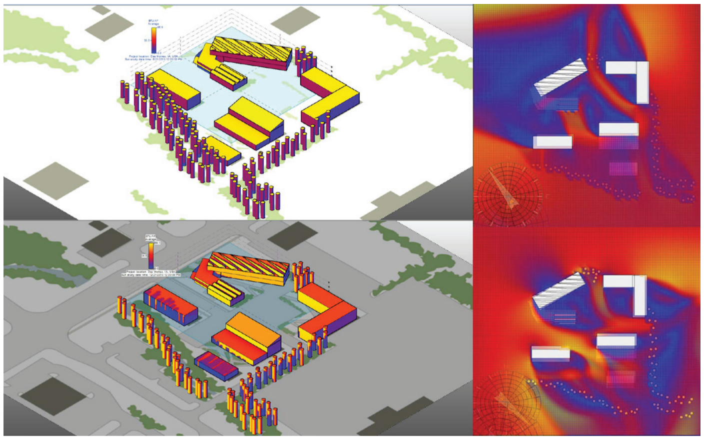

Figure 3. Site development using solar radiation and wind analysis tools (Adrienne Nelson, Amanda Havel and Melissa Goodwin).

the immaterial nature of environmental forces and heat transfer as Malwaki noted already in 2003, that “scientific visualization of processes which are usually not perceivable by the eye, are made visible through a color coding.”[13]

Simulation tools can help in understanding the impact of outdoor environmental conditions on building interior behavior by revealing the environmental context of solar radiation, its geometry, and topography as well as wind analysis. The real benefit for the designer is that these tools allow to focus on the energy flow path as a major design goal and they enable to compare a broader range of design iterations with multiple often conflicting parameters and inform the decision making process based on design intent and concept.

Analysis and design are now not exclusive activities anymore, but lead to performance optimized design based on the evaluation of performance indicators. With the goal to design low energy buildings, it has become increasingly important to understand the dynamic nature of the building performance throughout the seasons and not only on extreme days. From these experiences, the ISU Net-Zero Studio hopes its students learn how relatively easy it is to design net-zero buildings by beginning with that goal in mind and testing assumptions against actual numbers as the proposal is conceived, composed and completed.[14]

DESIGN INTENT AND VALIDATION

The students in the Net Zero Design studio operated in design teams of three and developed their design intent based on the pro-

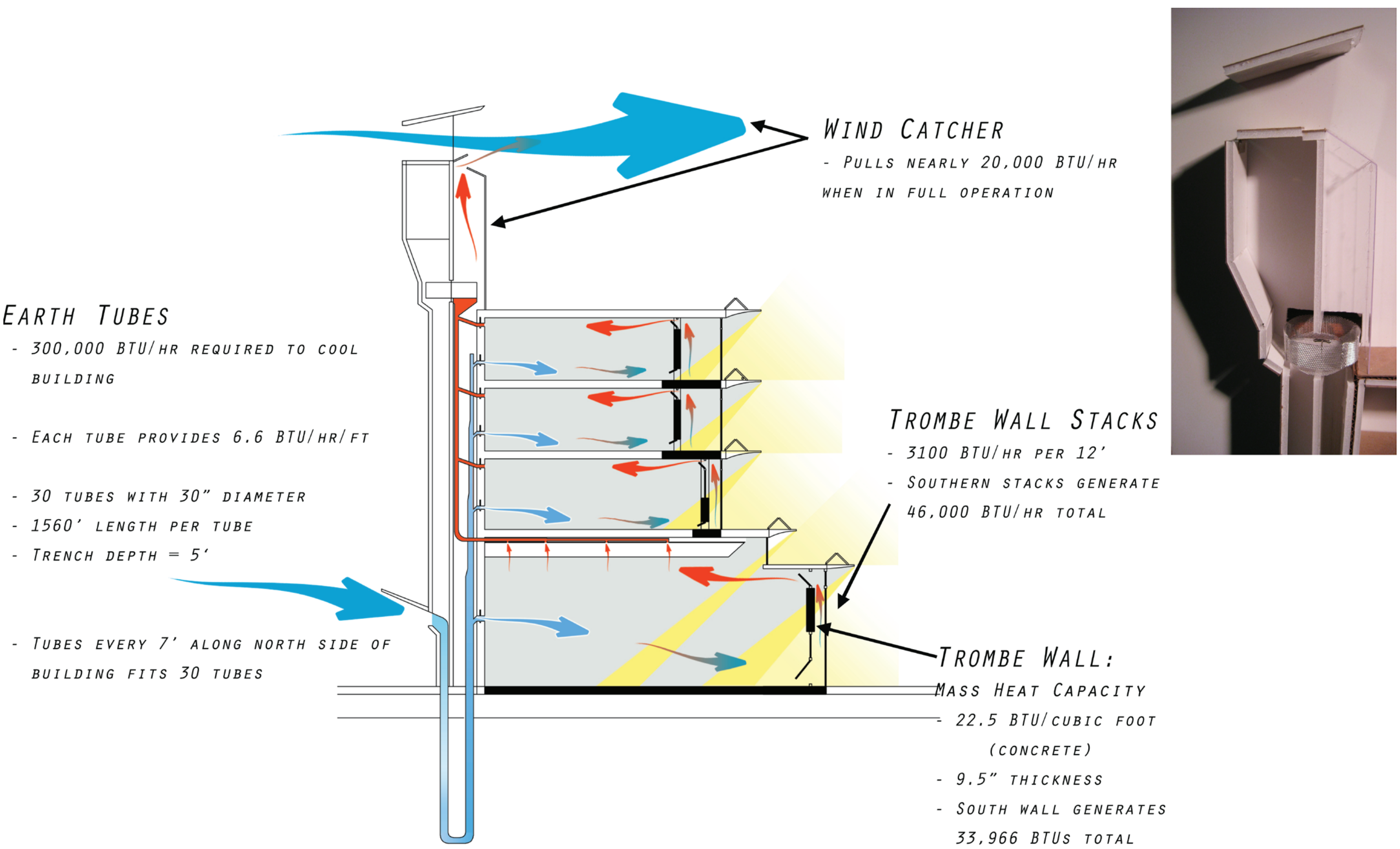

Figure 4. Design integration of a spatial environmental feature: The wind catcher (Firas Al Shalabi, Alexandra Evans, Katherine Dostart).

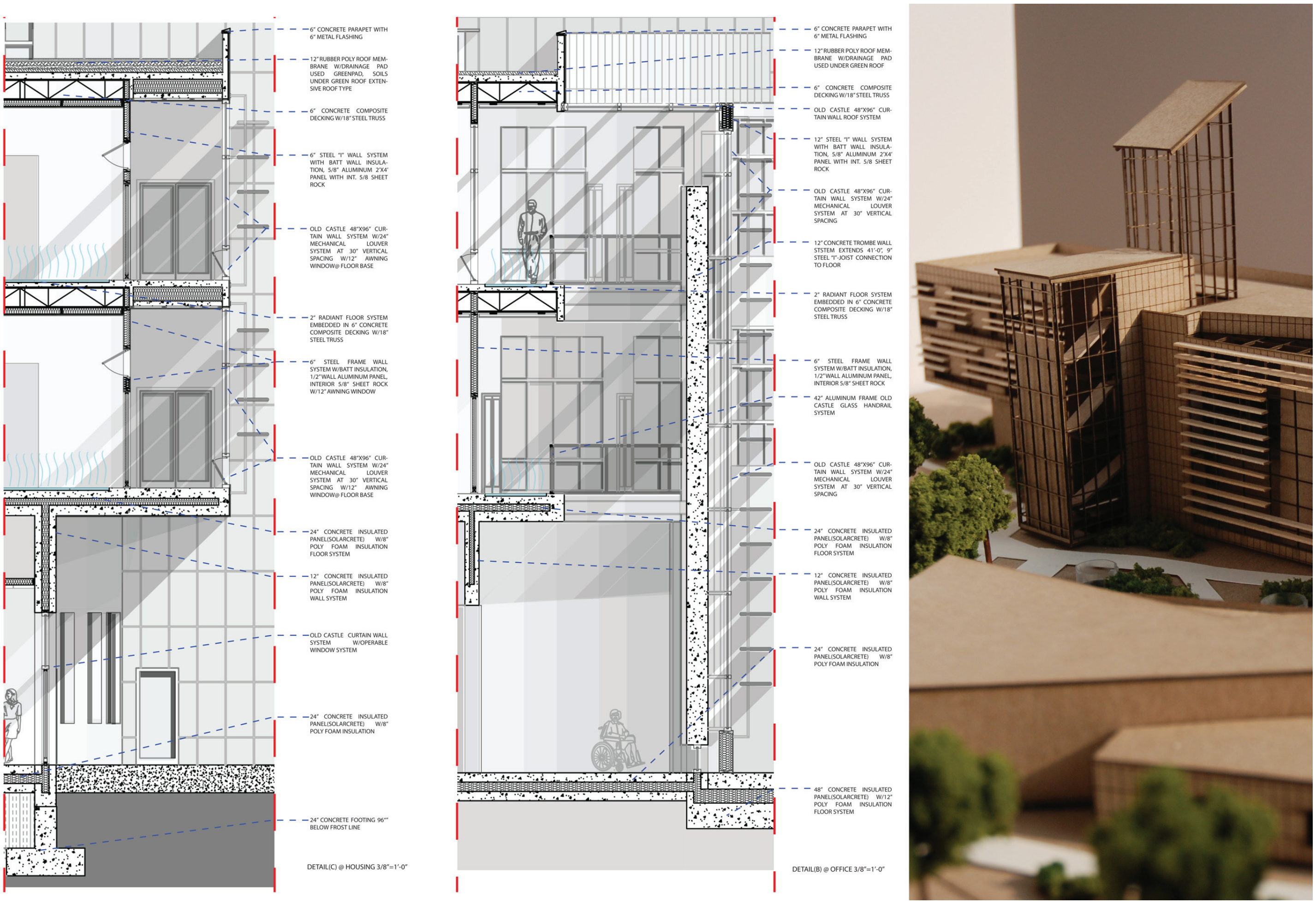

Figure 5. The building envelope as thermal capturing device (Xuefeng Zhong, Gregory Uhrich, Tim Lewis).

gram, site context and environmental performance goals. The first team project to highlight was designed by Adrienne Nelson, Amanda Havel and Melissa Goodwin, who developed their site configurations based on prevailing wind patterns and solar exposures. The team proposed to develop a low rise neighborhood with medium density, but distinct spatial determination on a currently empty and disused, but still impervious parking lot, which provided a large open site with optimum exposure to solar radiation, but no spatial context (Figure 3).

The team also addressed social and programmatic issues by selecting to develop a Neighborhood Finance Corporation & Tool Lending Library. The wind flow simulation conducted with Autodesk Vasari attempted to optimize the usability of the courtyard space by enhancing summer breezes and reducing the impact of fierce winter winds. The top row of images show the solar radiation, left in summer, right in winter and below the wind velocity around the buildings, left in summer and right in winter. The idea was to facilitate natural cross ventilation in summer and block the northern wind in winter. More important than the actual validity of the data is a pedagogical approach that enables the students to interpret the information obtained from the simulated results.

ENVIRONMENTAL FORCES AS SPATIAL DESIGN STRATEGY

For two teams the design challenge culminated in the development and integration of passive spatial strategies into programmatic concept. These projects understood that energy forces could be enhanced spatially without adding any technical gadgets. One of these teams integrated a solar chimney into their spatial composition and the other one also added a tall vertical element into their composition, this time as a wind catcher combined with a solar chimney.

The performance of these vertical elements is based on the stack effect, where hot air rises. A pressure differential above a neutral plain has proven to be a very effective design strategy to facilitate natural ventilation in locations, where wind is not always present. The project in Figure 4 developed a wind catcher with an integrated desiccant dehumidification wheel, which is connected to an earth tube, while the group of Gregory Uhrich, Tim Lewis and Xuefeng Zhong (Figure 5) utilized the upper portion of their stair case as a solar chimney. Unfortunately, the simulation of these complex thermodynamic systems is not yet easily available within the current set of tools and thus intuition, rules of thumb and spreadsheets substituted the digital tools.

Building envelope strategies

Another important design feature was the development of the building envelope to be implemented. The building envelope incorporated diverse and complex external shading devices and a solar thermal storage (Trombe) wall as high as the whole three story building. This wall delays the solar gain till later in the day for evening classes matching the environmental strategy with the schedule and the program.

COMPARATIVE CONCLUSION

Iterative processes with multiple conflicting variables have long shaped architectural design strategies. Generative design, associative design, conceptual design, metaphorical design, structural honesty, functionalism, postmodernism worked with visual metaphors, digital or mathematical form generators, associative images, languages or words. Forms have been distorted, destructed or morphed. With improved computation capacities design concepts, which can now integrate dynamic environmental performance goals as parameter into the form finding process might change form sustainably, so that a building would change like a chameleon from summer to winter. But the tool itself is only as valuable as the coherent design concept.

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ENDNOTES

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