The Missing Link in Architectural Pedagogy: Net Zero Energy Building (NZEB)

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> During COVID we learnt that no one is safe until everyone is safe, so we need to act urgently to protect the most vulnerable in society – in schools, hospitals, and homes for the elderly – in a movement that elevates buildings beyond being simply tradable assets, to seeing them as part of a built environment that is at the vanguard of our fight for a safer future for all. –Sue Roaf, Emeritus Professor of Architectural Engineering, Heriot-Watt University

Introduction

By 2050, Texas will have 115 heat days a year, 55 days more than on average in 2022 [1]. According to the US Census Bureau report 2022, San Antonio, Texas, topped the list of the most significant numeric gainers in the USA, increasing by 13,626 people between 2020 and 2021 [2]. This population growth increases the demand for space and energy. Ed Mazria, a founder of Architecture 2030, believes that the built environment generates nearly 50% of annual global CO_2 emissions. Building materials and construction account for 20% of this amount and building operation to 27% [3]. Both the NZEB design and construction play crucial roles in this region, therefore spotlighting architects.

Academics typically emphasize theorizing the design process in reverse order by setting goals, identifying evidence of learning outcomes, and designing the

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instructional plan as goals set forth according to the Paris Accord.[1] These goals are as follows:

- State current environmental circumstances;
- Select international sites to familiarize students with overseas climatic changes;
- Recognize future climatic changes;
- Extrapolate future resources, demands, and technologies;
- Implement advanced performance modeling to reduce energy consumption;
- Cooperate with construction industries, community, and other stakeholders;
- Design a net zero energy building with emphasis on maximizing the passive system through different architectural design concepts;

According to the New Building Institution (NBI), out of 56 verified NZE offices in the USA, only one branch exists in Texas[2] [5] (Fig. 1). The 17 third- and fourth-year undergraduate architecture students enrolled in the ARC 4156 Building Design studio course, entitled: Net Zero Energy US Embassy, US Consulate architectural design in different countries like Colombia, Dominican Republic, Greece, Japan, Norway, and Mexico.

Most of the students taking this studio course also took the ARC 4183 lecture course on environmental systems, which primarily focused on designing environmentally responsive buildings and the natural and artificial systems supporting them, i.e., embedded energy, active and passive heating cooling systems, and so

Fig. 1 HARC's energy manager explains how beekeeping helps the local ecosystem (left). Students promised to design NZEB at the end of the field trip to Houston and Woodlands at the beginning of the semester, HARC, Woodlands, TX (right) (Image represents the students' engagements and beginning potential for designing NZEB, and it stayed by the end of the semester). (Source: Author (2022))

[1] The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris on 12 December 2015 and entered into force on 4 November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 °C, compared with pre-industrial levels [4].

[2] The first NZE office in Texas is named HARC and is located in Woodlands. The studio had a site view at HARC.

on. Therefore, the students taking the theory course could practically apply those theoretical discussions in their studio projects.

Passive Design Strategies

Vernacular architecture presents perfect examples of inspiring passive design strategies to solve climate conditions without using fossil fuel energies and, in some cases, no modern construction machines or technologies (Fig. 2).

Every two or three students chose one country and conducted research on their climate zones. Using sources like Google Map and Google Earth, they discovered and analyzed their sites. Variable sites and climatic conditions in different countries provided a pedagogical opportunity for students to familiarize themselves with opportune climatic zones and their respective climate changes.

Premised upon passive design, resource conservation, and passive and active cooling and daylighting, conserving embodied energy base can significantly reduce gas and fuel consumption. Depending on their project site selection, each student in this design studio chose specific strategies adopted and used in various parts of the world. One of these solutions had to do with spatial scarcity predicting a significant reduction in spatial needs over the foreseeable future.

Sustainable Landscape

Students paid particular attention to using and enhancing public transportation, worked on the pedestrian paths surrounding bus stations, designing the necessary street furniture, and bicycle racks, and social and welfare amenities, i.e.,

Fig. 2 The student worked at the NZE US consulate at Barranquilla, Columbia, and used wind captures to provide natural ventilation inspired by Middle East countries' vernacular architecture. (Source: Erik Ortega (2022))

Fig. 3 All students focused on their site interventions and their impacts on local ecosystems. For example, one student designed the US consulate in a hot and humid climate zone (Santa Domingo Republic). He incorporated using low albedo materials, fauna, and flora in his design, where his passive design strategies provide appropriate shading areas and natural ventilation methods. (Source: Jhardon Small (2022))

supermarkets and food stores near them. Depending on the climate, flora and fauna play essential roles in creating shades and cooling systems apropos of designing sustainable landscapes, where rainwater serves irrigation purposes (Fig. 3).

Reducing the albedo effect is responsible for 23% of the global emissions – most of which are used in the built environment. This prompts incredible opportunities for embodied carbon reduction in high-impact materials [3].

Conceptual Architectural Design

A variety of reactions regarding architectural concepts had been seen in this stage of the design process: biomimicry, biophilic, vernacular, and sustainable architecture, and sometimes a combination to achieve better results (Figs. 4, 5, and 6).

When the time came to conserve historical buildings and save embodied energy, another student gave a new face to a historical US consulate building in Tokyo, Japan, by remodeling the building and using passive design strategies.

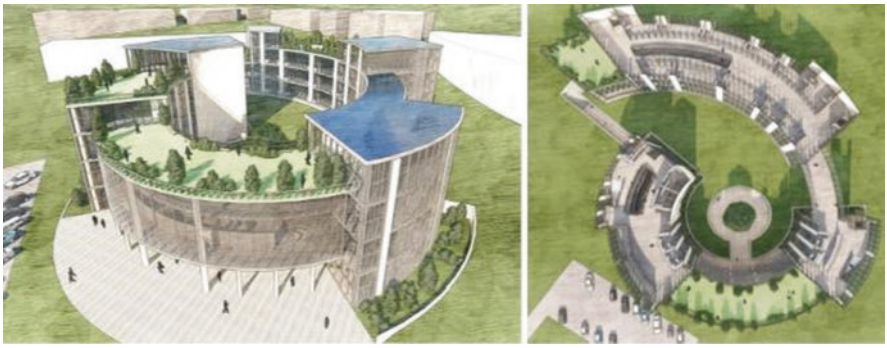

Fig. 4 Student work: A bird perspective (left), floor plan (right); one student represented a biomimicry design using golden ratio geometry as his concept. He was also inspired by Greek theater forms for designing the US embassy at Athens, Greece. (Source: Covey Johnson (2022))

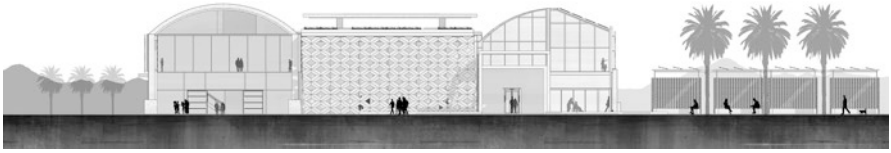

Fig. 5 Students work at Ciudad Juarez, Mexico, with a hot and dry climate zone; one student, inspired by some vernacular architecture strategies, used arches that provide a passive cooling system. Thanks to the arch form, half of the arch would be shaded during the day except at noon. (Source: Samuel Ruan (2022))

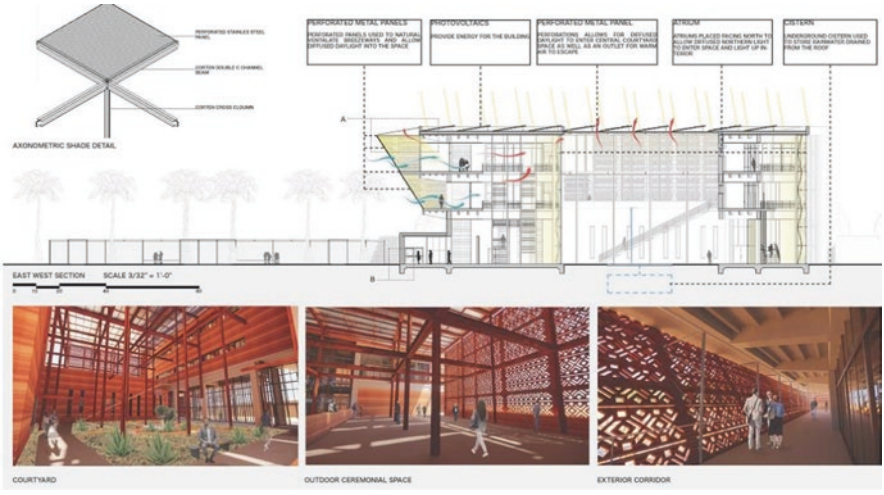

Fig. 6 Students work at Ciudad Juarez, Mexico; one student's passive cooling strategy included a courtyard and covered pedestrian path to provide a thermal landscape. (Source: Noel Parra (2022))

Sustainable Materials

Students were instructed to use recycled, local, low-carbon, and carbon-neutral materials. One student used plant-based concrete because it is eco-friendly and Avi-protect glass. Avi-Protect glass is an eco-friendly solution to saving flora and fauna. Birds lose their lives flying into reflective buildings by hundreds, so to counter that, the glass is acidly etched, allowing the birds to see it while not distracting by the facade. Another student reached out to use autoclaved aerated concrete, known as cellular concrete, and 100% natural materials.

Active Design Strategies

The studio familiarized the students with the world's renewable energy sources, including the photovoltaic cells on rooftops and building facades geared toward generating clean energy. The students used some of these devices as canopies or roof overhands in designing covered parking spaces. One student used a composition comprising PV cells and green surfaces that, in addition to natural ventilation and daylight, generated electricity as part of a green façade and collected the rainwater for watering the landscape and green panels (Fig. 7). Other students used the following design methods in their projects: recycling and reusing wastewater, flexible or movable walls for interior design as needed. Geothermal energy, especially in Oslo, Norway, inspired yet another renewable source that students used.

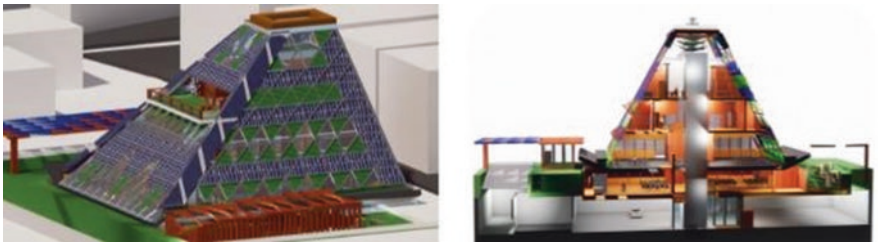

Fig. 7 Student work: One student practiced designing the NEZ US consulate in Fukuoka, Japan, and minimized the ratio of surface/volume; four facades have different designs based on their orientations. They provide natural ventilation and daylight. They combined PV panels with green panels. The façade panels are kinetics. The corridor in the center of the pyramid acts as a chimney effect. During our field trip, the student inspired the façade pattern from one of Houston's Fine Art Museum artworks. (Source: Udal Kosta (2022))

Results and Discussion

Luckan (2014) discussed embedding "sustainable design principles" into architectural design studio curricula [6]. Oliveira (2017) also shared the benefits of interdisciplinary or cross-disciplinary approaches to fill the existing theory-practice gap in architectural education. These strategies show how to incorporate sustainable development into architectural design [7]. Similarly, Azari and Caine (2017) demonstrated how to weave technical expertise – especially adding different methods of building performance evaluation – into architectural studio pedagogy [8]. In another research, Malini (2020) acknowledged the unpreparedness of architectural students in addressing the negative consequences of climate change and believes that "traditional design studio pedagogies" do not promote the culture of "cooperation and collaboration" among students. The undeniable fact remains that students learn from co-learning and sharing works, which, in some cases, helps them design more efficient buildings closer to net-zero goals, i.e., reducing energy demands to about 70% (ibid.) [9].

Therefore, according to Moosavi and Bush (2021), educating sustainability should be incorporated into architectural education. In their experience, the students simulated real-world scenarios in creating sustainable design strategies in their studio projects [10]. Mohamed (2022) also emphasized similar recommendations in incorporating sustainable design strategies into the architectural design curricula [11].

The word integration in architectural education has witnessed some changes since 2014. Integrating studio courses with sustainable design principles between 2014 and 2020 is a case. The 2050 achieve zero-carbon emission goals have incorporated even more pedagogical techniques in recent years. Combining these skills goes beyond teaching the students how to design NZE buildings and creates broader links for connecting the construction industry and community partnerships. Such new and integrative linkages can help thrive and develop new construction skills.

Conclusion

The learning outcomes of NZEB in the UTSA design studio pilot project include the following:

1. Innovation integration model between the academia, profession, and community (Fig. 8)
    1. Link between A and P
        - Expediting and expanding the NZEB projects.
        - Reducing the time to reach the set goals.

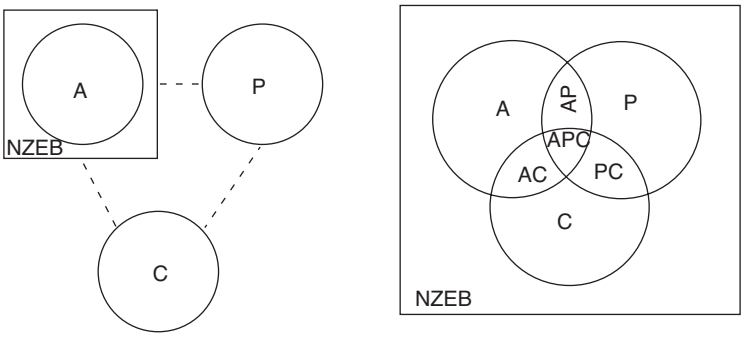

Fig. 8 Compares the unlinked (left) and linked (right) connections or relationships between the academia, the profession, and the local community in the area of NZEB studio. Specifically, the point shows two connections that seem more realistic and suitable to students and their communities (Source: Author (2022)). Note: A = Academia; P = Profession; C = Community; AP = Academia and Profession; AC = Academia and Community; PC = Profession and Community; APC = Academia, Profession, and Community

- The jury feedback shows more enthusiasm toward these projects than the students' purely conceptual projects, which ultimately boosts interdisciplinary professional creativity.

2. Linking A and C relationships leads to optimization of the NZE building

- The community part of the studio jury who came from the Mexican Consulate invited us to have an exhibition in the Consulate building.
- Social media can also promote this building construction approach within the community networks.
- The final project review also further strengthened the community, Mexican Consulate relationship.

The students learned a lot from the professional feedback for their projects and self-reflection. This relationship also helped them find summer internship employment opportunities in San Antonio construction companies.

The final jury demonstrated student satisfaction with this project. With its "international" concentration, this studio encouraged some students to pursue UTSA study abroad in Urbino, Italy, for the next semester (Fig. 9).

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Fig. 9 Final review day of the studio at UTSA. The image represents the integration of the academics, professionals, community members, and students who are aiming to "build an environment that is at the vanguard of our fight for a safer future for all." (Source: Author (2022)). Note: The quote is from Sue Roaf

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