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Creating an Undergraduate Multidisciplinary Design Research Team to Achieve Zero Energy

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Abstract

Creating an Undergraduate Multi-Disciplinary Design Research Team to Achieve Zero Energy

This paper will describe Indiana University Purdue University Indianapolis (IUPUI) Department of Engineering and Technology's multi-disciplinary project team developed to compete in global competition to achieve a Zero Energy building design. Combining the efforts of five different degree programs (Electrical Engineering Technology, Computer Graphics Technology, Architectural Technology, Interior Design Technology, and Construction Management) coursework, we are researching and developing a four-story building based on shipping containers as the starting shell building science. In a department where programs routinely operate in silos, this project is encouraging cross course communication as the building takes shape. Incorporating the Building Information Modeling (BIM) approach, the students in the Architectural Technology program are charting the initial path with the shell and master plan layout of the building. After the initial design development, we infuse the Electrical Engineering Technology students and work with solar energy with zero energy as their goal. The Interior Design & Architectural Technology students will begin partnering on designing the interior spaces for each dwelling unit in the building. We then bring in the Computer Graphics Technology design students to create the dynamic presentation imagery needed to sell the concept.

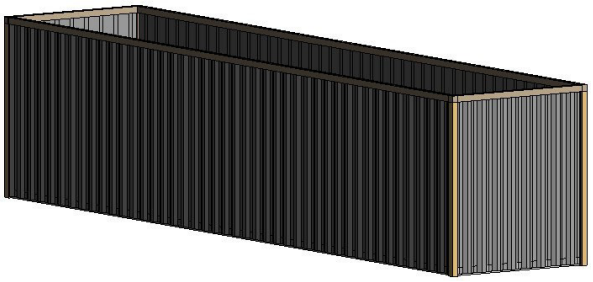
The Multidisciplinary Design approach has proven to be both challenging and rewarding in both industry and academia. Bringing together bright minds to attack a design problem functionally and systematically can test the boundaries of all team members. "*For some professionally, vocationally, or technically oriented careers, curricula delivered in higher education establishments may focus on teaching material related to a single discipline. By contrast, multidisciplinary, interdisciplinary, and transdisciplinary teaching (MITT) results in improved affective and cognitive learning and critical thinking, offering learners/students the opportunity to obtain a broad general knowledge base" Pooley*, Alison and Wanigarathna, Nadeeshani (2016).

Keywords
Shipping containers, Net-zero, Interactive learning, mentoring, evidence-based design.

Shipping Containers
The base constraint of the entire building study starts with the shipping containers. Spending the first 8 weeks of the semester in our Wood Frame Construction course developing design ideas for this multi-purposed, mixed-use building, the goal was to meet certain criteria points:

- Minimum of 8 dwelling units; building is up to 10 stories above grade.
- New construction or retrofit allowed.
- Building size: 350–2,000 ft^2 (33–186 m^2) per dwelling unit.
- Up to 50% of total area may be devoted to commercial use, such as retail, office, and industrial; remaining area is dedicated to residential use.
- For new construction, dwelling units must meet DOE Zero Energy Ready Home National Program Requirements (Rev. 07). For the commercial portion of building, the source EUI

must be less than the source EUI target shown in Table 1 in Section 3.1. Below in Figure 1.0 you will see the shipping container points of reference we began with.



- 40ft by 8ft by 9.5ft
- 320 sq ft
- Rugged steel construction
- Workhorse of the global shipping industry.

Figure 1.0 Shipping Container Data

Net-zero

The design objective is to reduce the carbon footprint with a zero-energy building. Creating a high-performance structure with a renewable energy system that in the long run can offset the building's energy consumption. "Commercial and residential buildings consume almost 40% of the primary energy in the United States or Europe, and nearly 30% in China [1], [2], [3]" (Deng, Wang, & Dai 2014). The chart in figure 2.0 shows the World Energy Consumption projections and how important a project like this can be in offsetting our growing energy use.

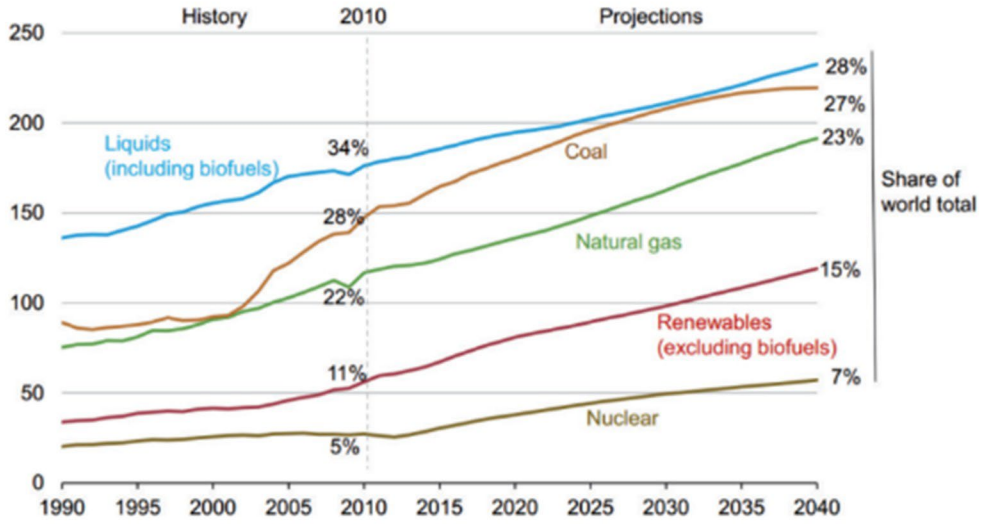


Figure 2.0 World Energy Consumption Projections

Interactive Learning

The Learning Spaces Design Team at Indiana University developed classroom that was primarily being used for the design development. The Active Learning Classroom of Valuable Experiences (ALCOVE), while still in its infancy stage as a teaching & learning space is well on its way to setting a new standard in the Indiana University system. Initially installed on the Bloomington Campus as a one-of-a-kind teaching space, the idea quickly grew into a model for duplication on other IU campuses. Whereas learning environment have typically referred to pedagogical design as well as cognitive and emotional space (including the online environment),

recently, the field is beginning to acknowledge and research the role of physical space in educational settings (Vercellotti 2018). Creating a space where the center of attention is not the traditional lectern and the professor at the front of the classroom, but instead with a mobile device such as a tablet the professor can matriculate through the classroom and interact with the students. VIA, the software application utilized in the space, has had mixed responses from students thus far, mostly due to the learning curve that comes with new technology. The software allows for both faculty and students to share information in large and small groups simultaneously.

Increasing student engagement was and is still one of the major on-going initiatives at IUPUI, and this new space is helping to do that. Interestingly, many of our studio workspaces for the Interior Design and Architectural Technology students are located in parts of the building that don't have windows. This new collaborative classroom has one oversized window, and the feedback was clear that it makes a huge difference, as some of the early survey feedback centered around the uniqueness of being in a classroom space with natural light. We now know that natural light impacts the working and learning environment in many ways, "Lighting in the classrooms has been the subject of many studies for over a century. In recent years, special attention has been given to the impact of natural light on learning as light has physiological, psychological, and behavioral influences" (N. Shishegar, M. Boubekri 2016).

Mentoring

Made up of 100% undergraduate students, this zero-energy team is studying repurposing shipping containers to create a mixed-use building that will function off solar energy. Putting together a multi-disciplinary team of students presents its fair share of challenges, however the mentoring opportunities that arise are priceless. This team was awesome to work with because their drive was unmatched. Thursday evening Microsoft Teams meetings, peer reviews of each other's design work, integrating multiple faculty, and so many other aspects could have been a recipe for a very dysfunctional team, however our group rose to the challenge. The very first and most important thing we did was develop the concept of what the building would look like and how it would function. This meant mentoring the team through of students through:

- Quality of the design and appearance
- Completing a market analysis
- Considering the occupant experience
- Maintaining professionalism at all times while working within the team

Some of the mentoring was planned intentional interactions and discussions, while other parts of it was in response to project objectives and instances as they arose. Specifically, one item that was unplanned of mentoring came after a pretty stressful presentation the student team made, and one of the team members completely froze during the Q&A session. Afterwards she apologized to me and the team, but I had to remind her that it happens to the best of us, and this would be great experience for the next presentation. I also advised her to go back and watch the recorded presentation to help prepare for the final one.

The other main mentoring scenario which went from project start to finish, was the building design itself. Undergraduates have a naive energy that is great to work with, and if driven in the right direction can work to generate some fabulous ideas. Keeping them within the parameters,

however, was a challenge. See figure 3.0 for the building specifics, and 3.1 for the concept rendering.

The five-story building with 24,240 square feet of useable space: two main levels to be commercial use spaces, and the top three levels will be a variation of living flats.	Level two: West wing: Commercial office space (approx. 1840 sq.ft.) East wing: Fitness center (approx. 1840 sq.ft.)
Level one: West wing: Coffee shop (approx. 1840 sq.ft.) East wing: Gaming space (approx. 1840 sq.ft.)	Levels three, four, & five Studio, 1 Bedroom, & Two Bedroom flats (700-1600 sq.ft.)

Figure 3.0 Building Specifications

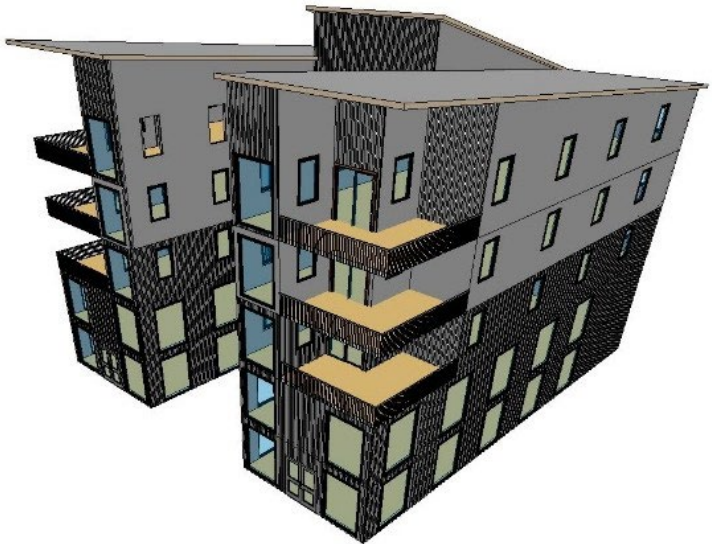


Figure 3.1 Concept Rendering

Evidence Based Design

An evidence-based design (EBD)-approach to the design process enables practitioners to fully meet human and environmental challenges (Cama, 2009; Hamilton & Watkins, 2009). In its original status, evidence based design was used in health care design development strategies to help create the most efficient user spaces. Utilizing measurable outcomes, practitioners take evidence-based design ideologies to forecast the success of the design idea while still in the ideation stage. This EBD approached charted our path for success, allowing our design team to keep focus on the end-user and their experience the moment they stepped foot into our building design. It also reminded us that every product needed a purpose, every building detail needed to meet some industry standard or best practice, and we constantly were looking to answer the question WHY.

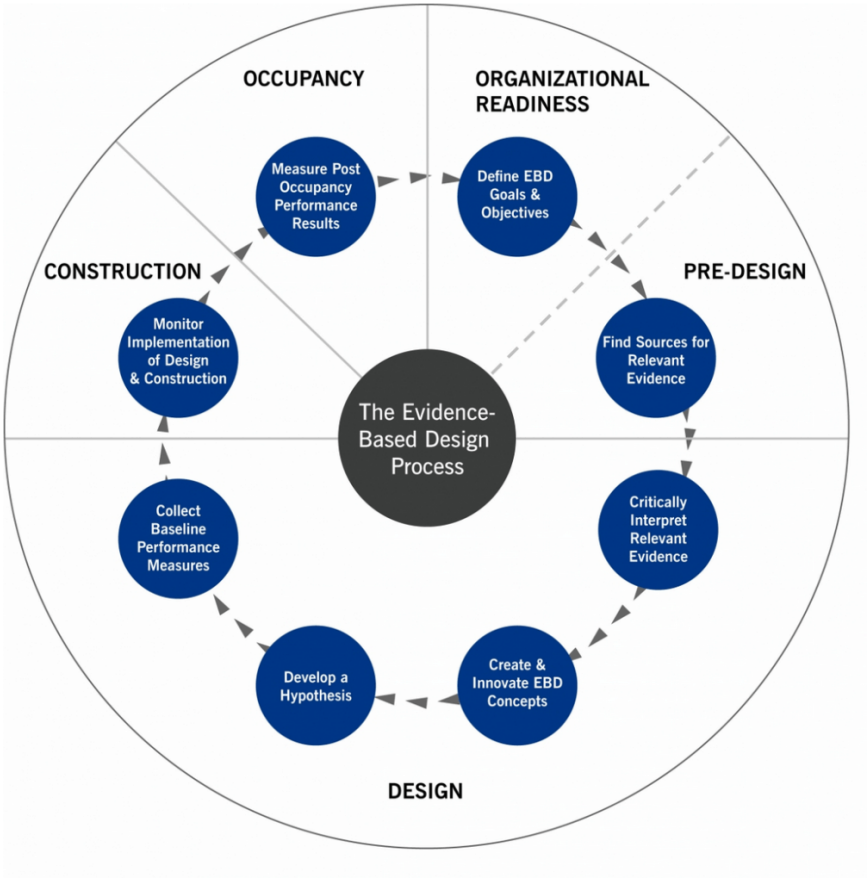


Figure 4.0 Evidence Based Design Diagram

The Design Team was comprised of students from three different programs, some working within the constraints of a course, others working independently, and some participating in both lanes. All student work was shared via MS Teams and reviewed weekly, then each team met weekly with the faculty team lead to synthesize thoughts, task, and assess the success of the energy efficient design. No face to face or virtual meetings ever took place between the individual courses participating on this project, which truly did challenge the written/non-verbal communication skills of the team overall. The student participation breakdown was as follows:

- Architectural Technology Wood Frame Construction course: 15 students tasked with developing building shell ideas for the competition. Each student presented ideas to the electrical engineering student team which then selected the entry to move forward with.
- Interior Design Technology Capstone course: 24 students tasked with leading the evidence-based design approach of the interior layout and functionality of the entire building. Building code and ADA analysis. Space allocations that meet today's standards.

- Electrical Engineering Technology students: 4 students lead the zero-energy building design & development.
- Department Faculty and Staff: faculty team leader, and four other department faculty helped to mentor the students for the year-long study.
- Industry Consultants: 3 Consultants helped research and vet the project ideas.

The overall strategy behind creating a team with this many moving parts was based on the notion of Asynchronous Learning, and growing on the lessons learned post-Covid, where like most universities we were forced to stay maintain productive teaching and learning environments while trying to work around many obstacles. “At the core of education is effective instruction. Whether looking to teach a skill, establish learning protocol, or connect with students, the instructional strategies used by teachers serve as the foundation of these efforts” (Erwin, Centeio, Beighle, McKown, G. 2021).

This experience has generated a lot of positive feedback among my faculty colleagues, industrial advisory board members, and the students, and has led to the tentative development of IUPUI’s first Multi-Disciplinary Capstone course that . This course will be a standard part of the curriculum in the Architectural Technology & Interior Design program, but will also be open to students in the in the other disciplines in our school, and will be centered around creating multi-diciplinary teams to compete in national and international yearly competitions such as IIDA, AIA, Solar Decathlon, etc. These institutions, and many others sponsor both annual competitions

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