Integrating Energy Simulation in Design and Construction Studios:

experiences from two undergraduate courses

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Integrating Energy Simulation in D/C Studios

Introduction

- **Sustainability ↔ Energy Consumption**

  Buildings used about 28% energy use (accounting for system losses, that number rises to 39%) (US-EIA, 2021)

  Design and construction decisions' impact on buildings operations

- **More collaborative methods – collaboration and understanding of different stakeholder perspectives**
- **More public (and clients') awareness towards environmental impact of buildings (Tan, Shen & Yao, 2011)**

- **Different AEC disciplines have different perceptions related to sustainability (Becerik-Gerber, Gerber & Ku, 2011)**
- **Lack of integration in teaching sustainable design and construction (Brncich et al. 2011).**

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Introduction

- **Purdue University**

  Creation of Design and Construction Integration (DCI) Major

  Focus on integrative topics to answer demand for higher levels of collaboration

  Two lecture / studios are offered:

  CM 33000 (sophomore)

  CM 33100 (junior)

  Studios are not only focused on design, but also understanding its implications towards construction and operations

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Background Literature

- Teaching Sustainability in other AEC programs

  40% surveyed programs using BIM to teach sustainability (Becerik-Gerber, Gerber & Ku, 2011) – architecture with higher emphasis, than E and C programs

  Software selection (Lewis et al., 2015; Rajagopalan, Wong & Andamon, 2016)

  Specifically to energy analysis to AEC students:

    Shen et al. (2012) – BIM and energy modeling (energy analysis and modeling iterations)

    Kim (2013) – focus on interpreting energy analysis

- Project Based Learning (PBL)

  + focus on real problem, student centered help increase student engagement and learning (Chinowsky et al. 2006)

  Project-based ↔ studio based learning – common in architecture education (Kuhn, 2001)

  Use of PBL in to teach design and construction integration (Barlow, 2011; Chinowsky et al., 2006; Siotiak & Walters, 2009; 2013)

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Methodology + Instructional Context

- Case study (CM 33000 and CM 33100)
  - SCMT
  - Studio courses – 6 credit hours total (4hs studio + 2h lecture)
    - 2 x 50min lecture + 2 x 4h lecture per week
    - Studios for both courses meet at same time
  - Required for DCI students
  - Pre-reqs:
    - CM 33000 - basic BIM course + building systems (+CM 20000)
    - CM 33100 – advanced BIM course + CM 33000 (+CM 30000)
  - Offerings:
    - CM 33000 – Fall 2019, Spring 2020
    - CM 33100 – Spring 2020, Spring 2021

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Case Study 1 – Energy Analysis in CM 33000

- Learning objective – implicit *("Exercise criticism in relation to built-environment design disciplines by taking user needs, aesthetics and technical demands into consideration at the same time")*
- Single-family small (500 – 650 sqft) home design (working with peers as clients / designer)
- Four deliverables: (1) site selection; (2) conceptual design; (3) schematic design; (4) design development

  In (3): Daylight analysis | Ideal R-value (walls) | Peak Heating and Cooling loads | Passive architecture

  In (4): MEP plans, energy assessment (yearly and monthly consumption), energy saving options
- 2 x 50 min lectures (integrating sustainability principles + passive design strategies)
- Technology: SketchUp + Sefaira

  Train students (2 studios) to introduce Sefaira + how to interpret results

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Case Study 1 – Energy Analysis in CM 33000

- + Software helped students understand impact of design choices
- - Introduction of software after conceptual design – students were somewhat fixed on their initial concepts
- - small home was already low on energy consumption, so changes in design had small impact on final energy consumed
- + many explored more efficient HVAC and Water Heating systems (split HVAC + tankless water heater) – but only one ventured on using solar panels
- + Interface of Sefaira built-in to Sketchup was helpful to students
- - Sometimes, too many options overwhelmed students
- + Web based application (Sefaira) helped when course had to migrate to online teaching due to COVID (Spring 2020).

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Case Study 2 – Energy Analysis in CM 33100

- Learning objective – explicit *("Identify sustainability, efficiencies and resource conservation principles to be applied in the built enviroment")*
- Commercial developments – development in group with individually designed buildings.

  Solar Decathlon Design Competition (from DOE) inspired deliverables
- Sustainability AND net zero buildings is a major portion of the course
- Four deliverables: (1) site selection; (2) conceptual design; (3) schematic design; (4) design development

  In (2): definition of target EUI, definition of MEP systems to reduce energy

  In (3): definition of energy goals / analysis. Revisions of EUI. Energy usage and power estimates. Financial study related to renewable energy options. Preliminary MEP plans

  In (4): Final EUI with MEP plans, summary of onsite and offsite renewable energy calculations. Summary of main inputs for energy model
- 11 x 50 min lectures related to energy design
- Textbook "Net Zero Energy Design: A Guide for Commercial Architecture" (Hootman, 2012).
- Technology: Revit + Energy Star Target Finder + PVWatts Calculator + Ekotrope Wall, Floor and Roof Calculator + Sefaira

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Case Study 2 – Energy Analysis in CM 33100

- - Spring 2020 class was limited in modeling due to the COVID-19 pandemic (switch to online learning)
- + In general, students were able to incorporate many energy saving options

  Focus on Net Zero design (even though they might not achieve it) helped
- + Use of high efficient systems (PV, geothermal…)
- + Integration between Sefaira and Revit
- - Reliability of numbers might be challenging (hard to assess)
- + Use of real project to teach efficient systems (especially geothermal) helped with student understanding

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Lessons Learned and Recommendations

- Technical issues with energy analysis software exist (similar to Lewis, 2015) - overwhelming options + number accuracy (checks)

- Lessons learned:

  Importance of energy analysis in an integrated design studio – students thinking long term about their design choices

  Novices may struggle with energy analysis software – scaffolding should be embedded in course to help students navigate software and interpret results

  Defining the right moment to introduce energy analysis – too early, students may not fully understand the impact | too late, students may be set in their designs

  For more advanced classes (CM 33100 in this case) – decide how much in depth to discuss mechanical systems (to not overpower class topics)

- Further studies:

  (1) determine students' understanding of energy analysis and its importance on the built environment

  (2) evaluating other energy analysis software that can be used in the course

  (3) determining the optimal point in which energy analysis should be introduced to students

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