From theory to practice: Assessing student progress in designing net-zero energy prefabricated buildings

by

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Abstract

Energy efficiency is becoming a key part of architectural education, making it important to understand how students engage with related design concepts. This thesis investigates how students' understanding of energy efficiency concepts developed over a semester-long studio course, participating in the Gateway Decathlon Project competition. The real-world interdisciplinary project involved designing and constructing a prefabricated net-zero energy building, giving students experience in applying energy efficiency strategies and solving real-world challenges in sustainable design. The study applied a longitudinal mixed-method approach to track students' learning progression over the semester. Data were collected through pre- and post-surveys, weekly observations, semi-structured interviews, and tracking building performance outcomes, which include source energy use and daylight analysis. Findings reveal that students developed a stronger understanding of how design decisions affect building performance, applied energy efficiency strategies more effectively, and benefited from interdisciplinary collaboration. Given that the final design was not fully constructed, the project experience still enabled substantial growth in students' ability to design a net-zero energy building. Overall, these findings suggest that hands-on, real-world learning experiences offer an effective approach to developing the knowledge and skills needed for sustainable architectural practice, particularly when aiming to achieve net-zero energy goals.

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CHAPTER ONE: INTRODUCTION

1.0. Chapter Introduction

As energy performance becomes a growing focus in architectural education and practice, students are increasingly expected to design buildings that meet high energy efficiency standards. Net-zero energy buildings (NZEBs), which aim to consume only as much energy as they produce, are becoming a common focus in design studios. However, the way these concepts are introduced and explored in architectural education is still not well understood. Despite the growing emphasis on sustainability in architectural education, research dedicated to tracking how students learn and progress in their learning of energy efficiency and NZEB design remains limited. Although earlier studies have examined the benefits of modular prefabrication and the possibility of interdisciplinary collaboration, they have tended to avoid identifying how students evolve in their understanding over time.

The limited research dedicated to identifying how students evolve in their understanding of NZEB design and energy efficiency constitutes a notable gap in literature. This gap poses challenges for educators wanting to determine how to best provide their students with the skills needed to understand and build sustainable buildings. Policymakers interested in promoting policy that advances NZEB sustainability may also encounter challenges without the requisite research, as would leaders in the construction and building industries, who invariably need a well-educated workforce capable of implementing energy-efficient design strategies. This study addresses the research gap and provides a comprehensive overview of project learning and how this learning guides sustainability education.

1.1. Topic Significance

Examining the environmental benefits associated with NZEBs, as well as how students acquire their knowledge and understanding of them, warrants scholarly attention for several reasons. The first is that climate change is endangering the planet, already drawing devastating consequences, and is likely to cause others as the climate changes. While addressing climate change demands a collective effort, one way to motivate sustainability is through education. In other words, students educated in sustainable methods are more likely to adapt them once they graduate and enter the world outside of academia, which in its own right reflects a second reason why this topic is essential. Finally, students who possess the knowledge and skills to design, implement, and advocate for NZEBs may encourage others to do likewise, if not in this specific domain, in others, helping to power the sustainability movement forward. By doing so, the likelihood that humanity faces the worst consequences of climate change decreases, thereby preventing the related problems that this environmental issue provokes. In short, the significance of this topic resides in nothing less than its implications for present and future generations.

1.2. Research Position

This thesis takes an informative approach to NZEBs and student learning, presenting a detailed analysis of how students learn about NZEBs and the preferred methods by which they learn. As such, it provides insight that educators, policymakers, and leaders in the construction industry and sustainability movement are likely to find useful.

1.3. Research Aims and Objectives

The aim of this research is to provide a detailed and comprehensive overview of the student experience and learning outcomes when building NZEBs. As for the research question and objectives, they are as follows:

Research Question: How does the progression of students' understanding of energy efficiency principles influence their ability to achieve net-zero energy buildings in their prefabricated house designs?

Objective 1: Highlight the most significant learning outcomes for students working with NZEBs, along with the challenges that may compromise these outcomes.

Objective 2: Offer evidence-based recommendations to guide future implementation of project-based learning in this area.

1.4. Thesis Structure

Without references, there are six chapters. The first is Chapter 1, Introduction, which features a chapter introduction, background, topic significance, research position, aims and objectives, and research methods. In Chapter 2, Literature Review, readers find subsections that include greenhouse gas emissions, net zero energy building (NZEB), modular prefabrication, and educating energy efficiency: tracking student progress in NZEB design. Chapter 3, Methodology, includes research methods, research design, study context and participants, data collection methods, data analysis methods, and Ethical Considerations. Chapter 4, Results and Discussion, presents the results and discussion of each finding separately, including pre- and post-surveys, interviews, observation notes, tracking building performance, and a brief section presenting figures of the hands-on construction experience. Lastly, Chapter 5, Conclusion, includes a contributed discussion, study limitations, suggestions for future research, and a conclusion.

CHAPTER TWO: LITERATURE REVIEW

2.0. Chapter Introduction

This literature review provides an overview of concepts related to net-zero energy buildings (NZEB) and examines previous research relevant to tracking student progress in understanding and applying energy efficiency principles to real-world prefabricated building designs. It focuses on several themes—greenhouse gas emissions, NZEBs, prefabrication and modularity, teaching energy efficiency and sustainability—that clarify the study's context and methodology and examines earlier studies tracking progress in similar contexts. Analyzing these topics will highlight the importance of sustainability and energy principles in architecture and showcase the tools needed to evaluate progress. Finally, this review will identify gaps in understanding how students' awareness of these concepts evolves and how it impacts their ability to design sustainable, energy-efficient real-world projects.

2.1. Greenhouse Gas Emissions

Primarily, climate change, the result of greenhouse gas (GHG) emissions accumulated in the atmosphere, is one of humanity's most significant environmental concerns.[1] In 2024, the buildings and construction sector contributed significantly to global climate change, accounting for approximately 21% of global GHG emissions, mostly due to increasing energy consumption.[2] Without action, buildings will continue to contribute substantially to global GHG emissions well into 2030 and beyond.[3] Adopting energy-efficient building designs and applying sustainable

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[1] "Causes of Climate Change - European Commission," accessed February 2, 2025, https://climate.ec.europa.eu/climate-change/causes-climate-change_en.

[2] United Nations Environment Programme, *2023 Global Status Report for Buildings and Construction: Beyond Foundations - Mainstreaming Sustainable Solutions to Cut Emissions from the Buildings Sector* (United Nations Environment Programme, 2024), https://doi.org/10.59117/20.500.11822/45095, ix.

[3] "Net Zero by 2050 – Analysis," IEA, May 18, 2021, https://www.iea.org/reports/net-zero-by-2050.

measures is critical to reduce energy consumption and GHG emissions in this sector. While energy-efficient building helps reduce emissions, NZEB introduces a more holistic approach to sustainability that can meaningfully reduce GHG emissions and help combat climate change.

2.2. Net Zero Energy Building (NZEB)

Relying on active and passive strategies, such as renewable energy and natural ventilation, NZEBs produce as much energy as they consume, leading to a reduction in the overall Source Energy Use (MBtu/yr).[4] This metric evaluates thermal performance and demonstrates the effectiveness of the strategies that NZEBs have incorporated. In addition, Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) evaluate daylight performance and improve energy use in buildings. Pellegrino et al. note that thermal and daylight analysis should be undertaken together to successfully optimize building energy performance.[5] While active and passive strategies improve energy performance and efficiency, the construction method itself plays a critical role when aiming to achieve NZEB. Prefabrication and modularity reduce material waste, energy usage, the overall carbon footprint, and long-term utility costs, making them vital components of NZEB.[6]

2.3. Modular Prefabrication

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[4] Esteban Estrella Guillén, Holly W. Samuelson, and Jose G. Cedeño Laurent, "Comparing Energy and Comfort Metrics for Building Benchmarking," *Energy and Buildings* 205 (December 2019): 109539, 2, https://doi.org/10.1016/j.enbuild.2019.109539; Mehrdad Shirinbakhsh and L.D. Danny Harvey, "Net-Zero Energy Buildings: The Influence of Definition on Greenhouse Gas Emissions," *Energy and Buildings* 247 (September 2021): 111118, 2, https://doi.org/10.1016/j.enbuild.2021.111118.
[5] Anna Pellegrino et al., "Impact of Daylighting on Total Energy Use in Offices of Varying Architectural Features in Italy: Results from a Parametric Study," *Building and Environment* 113 (February 2017): 151, https://doi.org/10.1016/j.buildenv.2016.09.012.
[6] Ravijanya Chippagiri et al., "Technological and Sustainable Perception on the Advancements of Prefabrication in Construction Industry," *Energies* 15, no. 20 (October 13, 2022): 7548, 2, https://doi.org/10.3390/en15207548.

The integration of prefabrication and modularity, modular prefabrication, yields greater benefits than separately employing these methods. The sustainability and affordability of modular prefabricated construction compared to traditional construction have increased gained public attention over the past few years.[7] Jiang et al. confirm that modular prefabrication performs more effectively than conventional construction in terms of "construction waste, aesthetic options, site disruption, water consumption, and pollution generation."[8] Additionally, several studies demonstrate that both prefabrication and modularity reduce construction time by up to 50%, saving labor costs and overall project expenses and making NZEB more affordable.[9] Besides its cost and sustainability benefits, modular prefabrication enhances building performance by improving insulation and airtightness, resulting in less operational energy consumption.[10] Even so, the implementation of modular prefabrication faces challenges, such as a lack of understanding and experience, a late design freeze, and poor collaboration and communication between project members.[11] Since modular prefabrication is necessary to achieve NZEB, addressing these challenges requires educating future architects and engineers on energy efficiency principles and modular prefabrication through a real-world project, which would give them the opportunity to apply and improve their design skills.

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[7] Aili McConnon, "Modular Construction Meets Changing Needs in the Pandemic," *The New York Times*, December 15, 2020, sec. Business, https://www.nytimes.com/2020/12/15/business/modular-construction-pandemic-coronavirus.html.

[8] Yongsheng Jiang et al., "Sustainable Performance of Buildings through Modular Prefabrication in the Construction Phase: A Comparative Study," *Sustainability* 11, no. 20 (October 14, 2019): 5658, 12, https://doi.org/10.3390/su11205658.

[9] V. Tavares et al., "Prefabricated versus Conventional Construction: Comparing Life-Cycle Impacts of Alternative Structural Materials," *Journal of Building Engineering* 41 (September 2021): 102705, 9, https://doi.org/10.1016/j.jobe.2021.102705.

[10] Sareh Naji, Lu Aye, and Masa Noguchi, "Multi-Objective Optimisations of Envelope Components for a Prefabricated House in Six Climate Zones," *Applied Energy* 282 (January 2021): 116012, 2, https://doi.org/10.1016/j.apenergy.2020.116012.

[11] Ibrahim Yahaya Wuni and Geoffrey Qiping Shen, "Fuzzy Modelling of the Critical Failure Factors for Modular Integrated Construction Projects," *Journal of Cleaner Production* 264 (August 2020): 121595, 2, 10, https://doi.org/10.1016/j.jclepro.2020.121595.

While many studies demonstrate the advantages of modular prefabrication, there is limited research on how students apply these techniques in their NZEB designs. Jiang et al. highlight the sustainability benefits of modular prefabrication over conventional approaches but do not explore how architecture students apply these techniques to their designs or how their understanding evolves over time.[12] Similarly, Wuni and Shen discuss the challenges of modular prefabrication, among them difficulties in its implementation, but focus on industry applications rather than how future architects and engineers learn to overcome these challenges.[13] Additionally, there is a gap in understanding related to how modular prefabrication improves the application of energy efficiency principles in NZEB student projects. Most existing studies fail to track student learning progression making it difficult to identify how they alter their designs as they acquire experience with modular prefabrication and energy efficiency strategies.

2.4. Educating Energy Efficiency: Tracking Student Progress in NZEB Design

Educating architects and engineers about energy efficiency principles and sustainability significantly impacts their ability to design NZEBs that reduce GHG emissions, promote affordable housing, and improve long-term building performance. The increased attention to energy efficiency and sustainability practices indicates that future architects must master advanced technical skills and environmental strategies to apply and implement these principles

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[12] Wei Jiang et al., "Energy-Saving Retrofits of Prefabricated House Roof in Severe Cold Area," *Energy* 254 (September 2022): 124455, https://doi.org/10.1016/j.energy.2022.124455.

[13] Ibrahim Yahaya Wuni and Geoffrey Qiping Shen, "Fuzzy Modelling of the Critical Failure Factors for Modular Integrated Construction Projects," *Journal of Cleaner Production* 264 (August 2020): 121595, https://doi.org/10.1016/j.jclepro.2020.121595.

effectively.[14] Roufechaei et al. argue that engineers must experiment with sustainability practices, securing an education that incorporates energy efficiency and sustainability.[15]

One of the most effective ways to educate engineering and architecture students about energy efficiency and sustainability is to have them collaborate on real-world projects. Research suggests that these students are typically not afforded an interdisciplinary education, which erodes trust between the disciplines and prevents adequate information sharing.[16] Early collaboration between architects and engineers ensures that both groups benefit from structural integration; while differing educational paths may create challenges between the two professions.[17] Collaboration between architects and engineers exposes them to real-world problems that bolster their practical knowledge and understanding of how to work with others.[18] A Delphi study on sustainability education highlights the importance of implementation competency, arguing the need for students to "learn from stakeholders how they have implemented change, [as well as] to practice it themselves by actually implementing a sustainability solution in a specific context."[19] Ruiz-Ortega et al. state that engineering students who participated in real-world projects significantly improved their motivation and academic

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[14] Paola Boarin and Antonio Martinez-Molina, "Integration of Environmental Sustainability Considerations within Architectural Programmes in Higher Education: A Review of Teaching and Implementation Approaches," *Journal of Cleaner Production* 342 (March 2022): 130989, 2, https://doi.org/10.1016/j.jclepro.2022.130989.

[15] Kamand M. Roufechaei, Abu Hassan Abu Bakar, and Amin Akhavan Tabassi, "Energy-Efficient Design for Sustainable Housing Development," *Journal of Cleaner Production* 65 (February 2014): 386, https://doi.org/10.1016/j.jclepro.2013.09.015.

[16] Jennifer MacDonald and Julie Mills, "An IPD Approach to Construction Education," *Construction Economics and Building* 13, no. 2 (June 20, 2013): 93–103, https://doi.org/10.5130/AJCEB.v13i2.3324.

[17] Guy Marriage and Joe Gamman, "Advancing Collaboration between Students of Architecture and Engineering," n.d.

[18] Anh L H Tran, Julie Mills, and Julie Mills, "'All Hands on Deck': Collaborative Building Design Education for Architects and Engineers," 8, n.d.

[19] Katja Brundiers et al., "Key Competencies in Sustainability in Higher Education—toward an Agreed-upon Reference Framework," *Sustainability Science* 16, no. 1 (January 2021): 24, https://doi.org/10.1007/s11625-020-00838-2.

skills.[20] Finally, Ahmed Kamal Ali notes that collaboration between disciplines benefits students and professionals and improves the overall industry, suggesting that better communication between disciplines is needed.[21]

While collaborative real-world projects provide students with valuable experiences in designing NZEB, tracking their progress can determine how well they apply energy efficiency principles in their design. Surveys, interviews, and observations provide qualitative insight into student learning progress. Pre- and post-surveys have helped researchers evaluate how student understanding of sustainability develops, and provided insight into their attitudes and confidence levels when applying sustainability principles.[22] A study examined interdisciplinary collaboration between architecture and engineering students using the Qualtrics platform for surveys to evaluate their perception of collaborative learning, project management, and the effectiveness of interdisciplinary teamwork.[23] After examining surveys through Qualtrics, the study analyzed the results using frequency distribution and mean calculations, revealing strong evidence that collaborative design-build experiences benefit students and overall architecture, engineering, and

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[20] Ana M. Ruiz-Ortega et al., "Project-Led-Education Experience as a Partial Strategy in First Years of Engineering Courses," *Education for Chemical Engineers* 29 (October 2019): 1, https://doi.org/10.1016/j.ece.2019.05.004.

[21] Ahmed K. Ali, "A Case Study in Developing an Interdisciplinary Learning Experiment between Architecture, Building Construction, and Construction Engineering and Management Education," *Engineering, Construction and Architectural Management* 26, no. 9 (September 4, 2019): 2040–59, https://doi.org/10.1108/ECAM-07-2018-0306.

[22] Shan He and Ulrike Passe, "ENERGY MODELING: A PILOT STUDY TO IMPROVE INTEGRATED," n.d.; Jill A. Marshall, Jay L. Banner, and Hye Sun You, "Assessing the Effectiveness of Sustainability Learning," Journal of College Science Teaching 47, no. 3 (January 2018): 57–67, https://doi.org/10.2505/4/jcst18_047_03_57.; Mary Katherine Watson et al., "Assessing Impacts of a Learning-Cycle-Based Module on Students' Conceptual Sustainability Knowledge Using Concept Maps and Surveys," Journal of Cleaner Production 133 (October 2016): 544–56, https://doi.org/10.1016/j.jclepro.2016.04.063.

[23] Ahmed K. Ali, "A Case Study in Developing an Interdisciplinary Learning Experiment between Architecture, Building Construction, and Construction Engineering and Management Education," *Engineering, Construction and Architectural Management* 26, no. 9 (September 4, 2019): 2040–59, https://doi.org/10.1108/ECAM-07-2018-0306.

construction industries.[24] While surveys provide valuable qualitative and quantitative data on student knowledge progression, interviews and observations offer more profound insight into how students apply energy efficiency principles in their design. Braun and Clarke emphasized the usefulness of thematic analysis for qualitative data, particularly data collected through interviews, to examine patterns of meaning in responses.[25] Watson contends that researchers cannot really learn about 'what happens' or 'how things work' in groups without intensive close observations.[26] Using observation and interviews, a related study examined how architecture students implement active and passive strategies, highlighting the role of passive methods in architectural design education.[27] Another study relied on the same methodological approach to explore how students engage with sustainability in design studios, showcasing that the studio environment encourages and motivates students to apply sustainability principles to real-world projects.[28]

Tracking energy performance helps evaluate student learning progress, as demonstrated by the *AIA 2030 Commitment*, which focuses on analyzing design performance and the effectiveness of applying energy principles.[29] A study on energy performance among architecture and engineering students used energy simulations to track their understanding of energy principles, measuring

[24] Ali, "A Case Study in Developing an Interdisciplinary Learning Experiment between Architecture," 2056.
[25] Virginia Braun and Victoria Clarke, "Using Thematic Analysis in Psychology," *Qualitative Research in Psychology* 3, no. 2 (January 2006): 77–101, https://doi.org/10.1191/1478088706qp063oa.
[26] Tony J. Watson, "Ethnography, Reality, and Truth: The Vital Need for Studies of 'How Things Work' in Organizations and Management," *Journal of Management Studies* 48, no. 1 (2011): 202–17, https://doi.org/10.1111/j.1467-6486.2010.00979.x.
[27] Zhi Qiu et al., "A Teaching Experiment in Architectural Design Focused on Efficiency: A Study on the Active and Passive Methods of Site Information Acquisition," *Buildings* 15, no. 4 (February 10, 2025): 540, 1, 22, https://doi.org/10.3390/buildings15040540.
[28] Robert Grover, Stephen Emmitt, and Alex Copping, "Critical Learning for Sustainable Architecture: Opportunities for Design Studio Pedagogy," *Sustainable Cities and Society* 53 (February 2020): 101876, https://doi.org/10.1016/j.scs.2019.101876.
[29] Kelly Pickard, *AIA 2030 Commitment: Measuring Industry Progress Toward 2030, Second Annual Report, May 2012* (Washington, DC: The American Institute of Architects, 2012), 3.

their progress through energy performance evaluation, design adjustments, and evidence-based reports.[30] Finally, related research used surveys, daylight simulations, and environmental monitoring to gather quantitative data, increasing architects' knowledge of daylight simulation results and connecting their professional experience with knowledge from simulation tools.[31]

Although energy efficiency and sustainability are becoming more noteworthy areas of focus in architectural education, there is still a lack of research on tracking student knowledge progression. For instance, the studies that use pre- and post-surveys to measure student knowledge of sustainability do not track the actual implementation of energy efficiency principles in real-world design projects.[32] Similarly, studies on real-world project-based learning show that exposure to practical implementation enhances student knowledge but offers little on how students apply energy efficiency principles to prefabricated NZEB designs.[33] Brundiers et al. study used purposive sampling and questionnaires to learn about key competencies in sustainability in higher education but did not track student understanding and their energy performance results over time.[34] Ambrose, Taheri, and Wood do not examine how students understand and improve their designs based on daylight and thermal analysis results over time.

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[30] Emilie Nault et al., "Energy Performance Analysis in Interdisciplinary Education – Lessons Learned from a Simulation-Based Teaching Approach," n.d.

[31] Kristen M. Ambrose, Helia Taheri, and Sarah Wood, "A Framework to Improve Designers' Understanding of the Quantitative Results of Daylight Analysis," *in Proceedings of the 108th ACSA Annual Meeting* (Raleigh, NC: Association of Collegiate Schools of Architecture, 2020), 153, 155. https://doi.org/10.35483/ACSA.AM.108.19

[32] Shan He and Ulrike Passe, "ENERGY MODELING: A PILOT STUDY TO IMPROVE INTEGRATED," n.d.; Jill A. Marshall, Jay L. Banner, and Hye Sun You, "Assessing the Effectiveness of Sustainability Learning," Journal of College Science Teaching 47, no. 3 (January 2018): 57–67, https://doi.org/10.2505/4/jcst18_047_03_57.; Mary Katherine Watson et al., "Assessing Impacts of a Learning-Cycle-Based Module on Students' Conceptual Sustainability Knowledge Using Concept Maps and Surveys," Journal of Cleaner Production 133 (October 2016): 544–56, https://doi.org/10.1016/j.jclepro.2016.04.063.

[33] Zhi Qiu et al., "A Teaching Experiment in Architectural Design Focused on Efficiency: A Study on the Active and Passive Methods of Site Information Acquisition," *Buildings* 15, no. 4 (February 10, 2025): 540, 1, 22, https://doi.org/10.3390/buildings15040540.

[34] Katja Brundiers et al., "Key Competencies in Sustainability in Higher Education—toward an Agreed-upon Reference Framework," *Sustainability Science* 16, no. 1 (January 2021): 13–29, https://doi.org/10.1007/s11625-020-00838-2.

These gaps suggest the need for an in-depth approach to tracking students' progress through surveys, interviews, observations, and building performance outcomes.

2.5. Chapter Conclusion

This literature review draws attention to the importance of energy-efficient design in reducing GHG emissions and mitigating climate change. It focuses on the critical role of energy efficiency in architectural education, particularly in designing modular prefabricated NZEBs and interdisciplinary collaboration. Additionally, it explores different methods that aim to evaluate student learning and understanding progression with energy efficiency concepts. However, existing literature lacks longitudinal tracking of student progressions in applying energy efficiency concepts in NZEBs and rarely combines mixed-method approaches to assess student knowledge development. This study addresses these gaps by employing pre- and post-surveys, observation notes, interviews, and tracking building performance. The next chapter introduces the study's methodology and details the approach adopted to assess student learning and design progression in achieving prefabricated NZEB.

CHAPTER THREE: METHODOLOGY

3.0. Chapter Introduction

The design of a prefabricated NZEB requires more than technical knowledge. Instead, it demands an in-depth understanding of energy efficiency principles and sustainable construction methods. This study examines how architecture students' knowledge of energy efficiency evolves over a semester-long design studio course and how their learning progress impacts their ability to design an NZEB. A longitudinal mixed-method approach is used to track how students' understanding of energy efficiency principles develops over time and how this progression affects their final design's energy performance and daylight outcomes.

The quantitative analysis involves tracking students' building performance results, including Source Energy Use and daylight performance assessment (sDA & ASE), to evaluate the relationship between design decisions and an evolving understanding of energy efficiency principles. Surveys administered at the beginning and the end of the semester help measure changes in their knowledge of energy efficiency. While these methods offer measurable data on student designs, a qualitative approach yields deeper insight into the reasoning behind student design decisions. The qualitative analysis includes weekly observations of students' design decision process, open-ended survey questions, and semi-structured interviews. Lastly, this chapter will discuss research design, study context, data collection methods, data analysis methods, and ethical considerations to ensure that the research is valid and reliable.

3.1. Research Design

The study applies a longitudinal mixed-method approach embedded in a semester-long architectural studio, participating in the Decathlon Project, which focuses on achieving a net-zero energy prefabricated house. Using triangulation, quantitative and qualitative data from surveys, interviews, observations, and building performance tracking are combined, providing a detailed analysis of student learning and design progress. Lastly, the approach offers an extensive examination of measurable design data while capturing the development of students' knowledge throughout the semester.

3.1.1. Longitudinal Approach

The longitudinal approach involves tracking changes in students' knowledge, design choices, and building performance throughout the semester rather than relying on a single-stage assessment. Collecting data at multiple stages offers a clearer picture of the student learning process and design changes using energy efficiency concepts over time. Notably, repeated data points allow for documenting trends, patterns, and the implication of iterative design adjustments. Lastly, the approach ensures a systematic analysis of students' design outcomes and adaptation to energy efficiency strategies.

3.1.2. Quantitative Method

The quantitative method involves tracking energy use and daylight performance (sDA & ASE) outcomes, along with pre- and post-surveys that assess theoretical and technical understanding of energy efficiency principles. Monitoring performance data over time enables an understanding of how students' design strategies may evolve and offers measurable data on whether these refinements improve energy performance and align with their learning progress.

3.1.3. Qualitative Method

Qualitative analysis, which includes observations and interviews, helps explore design processes and decision-making strategies that help students achieve better performance results. It also helps reveal how an evolving understanding of energy efficiency principles influences students' ability to achieve a net-zero energy prefabricated house. Additionally, it highlights the effectiveness of engaging in a real-world project and examines how interdisciplinary collaboration shapes students' final design outcomes.

3.1.4. Triangulation Approach

Triangulation strengthens the study's validity and enables consistency over multiple sources by combining quantitative and qualitative data. Surveys, observations, and student reflections are analyzed alongside building performance outcomes to confirm trends and reduce bias. This approach links energy efficiency improvements to student decision-making, offering a well-rounded evaluation of learning and design progress.

3.2. Study Context & Participants

This study took place within an architectural design studio participating in The Gateway Decathlon Project competition. The Gateway Decathlon Project is an international competition where university teams design and construct innovative housing that addresses key challenges in the future of housing, including energy efficiency, sustainability, and affordability.[35] The competition involved designing a modular prefabricated house, which will be transported to the competition site for installation. Since this competition requires constructing a real-world building, participation allows students to work on conceptual and real-world applications. Moreover, it reveals challenges encountered in professional architectural practices, helping

[35] "COMPETITION DETAILS," Gateway Decathlon, accessed February 20, 2025, https://gatewaydecathlon.org/competition-details.

students gain valuable problem-solving skills and a deeper understanding of energy efficiency principles.

Study participants were selected using purposive sampling, where data collection focuses on students actively involved in the studio designing NZEB for the Decathlon Project. Sixty students participated in the study and were categorized into three groups: fourth-year architecture students, fifth-year architecture students, and architectural engineering students. Students were divided into ten teams, each of which was responsible for different aspects of the Decathlon Project competition, whether performance, envelope, or systems teams. Dividing students into groups allows those from different academic backgrounds to work together to achieve NZEB. Following this, the collaboration between architecture and engineering students promotes an interdisciplinary learning environment and interaction and enhances the learning process as students from different backgrounds consider multiple perspectives to achieve net-zero energy efficiency.

Participants were selected based on their enrollment in the Decathlon Project design studio course, active involvement in the design process, and commitment to participating in all data collection activities. Students who were not enrolled in the design studio course, failed to participate in the design process actively, or missed significant studio time were excluded to maintain consistency and reliability.

3.3. Data Collection Methods

Data is collected during three main stages: pre-semester baseline evaluation, mid-semester observations and tracking, and end-of-semester evaluation. First, the pre-semester baseline evaluation includes a baseline survey that assesses how much students initially know about energy efficiency principles. During the semester, weekly observations track students' design decisions, while performance data, including energy use and daylight metrics, is periodically collected. Finally, the end-of-semester evaluation consists of final surveys and semi-structured interviews, which provide insight into challenges that students confronted, how their understanding evolved, and how they applied energy efficiency strategies to their final design.

3.3.1. Surveys

Surveys were conducted online using Qualtrics and were distributed to students via email at the beginning and end of the semester. The surveys were sent to 60 students enrolled in the Decathlon Project design studio. However, only 23 completed both the pre- and post-surveys. The pre-survey assessed the baseline of students' initial knowledge before they began working on their project, while the post-survey measured changes in knowledge after completing the course. It also measured how confident students felt in applying energy-efficient strategies in their design.

The pre-survey included both qualitative and quantitative question formats. The quantitative questions consisted of Likert-scale and multiple-choice questions to examine students' familiarity with energy efficiency concepts and tools, confidence in designing NZEB, and technical understanding. The qualitative section included open-ended questions to explore challenges students faced, initial design strategies, and deeper learning experience insight. The post-survey consisted of Likert-scale and multiple-choice quantitative questions to evaluate how student understanding evolved throughout the semester. Once survey responses were collected, the data were exported from Qualtrics and organized in an Excel spreadsheet for further analysis. Both pre- and post-survey raw data are demonstrated in Appendix A.

3.3.2. Interviews

After students completed their design project at the end of the semester, semi-structured interviews were conducted to gain insight into students' learning experiences. Using purposive sampling, a total of ten students were selected based on academic background and project role. The diverse selection provides a variety of viewpoints for richer discussions and analysis of their learning process. Additionally, selected students actively integrated energy efficiency principles and evaluated building performance, making their reflections relevant and valuable for research objectives. Participants consisted of four fourth-year architecture students, four fifth-year architecture students, and two architectural engineering students. Among the architecture students, two fourth-year students were part of the performance team, and two were part of the envelope team. The same structure was applied to the fifth-year architecture students, with two in the performance team and two in the envelope team. The two engineering students were on the performance team and worked on energy efficiency and building performance analysis alongside other team members.

The interviews took place in a separate room next to the studio, increasing the focus of the discussion and preventing unwanted distractions. Each interview was carried out one-on-one, allowing students to discuss their opinions and share their experiences in depth. Students responded verbally, and no written answers were collected. All interviews were voice-recorded using a password-secured device during the sessions to maintain reliability and data integrity. Once the interviews were completed, the voice recordings were manually transcribed into a Microsoft Word document, as shown in Appendix B, on a password-protected computer. Each interview session lasted between 10 and 15 minutes, allowing participants enough time to clarify their responses.

The semi-structured interviews consisted of 18 questions scripted in a Microsoft Word file, combining scaled rating questions and open-ended prompts. The questions were divided into five sections: student understanding and learning experience, design decisions, software and tools, interdisciplinary collaboration, and key takeaways. These questions were designed to explore the understanding of energy efficiency, the use of performance tools, interdisciplinary collaboration, and key takeaways from the project.

3.3.3. Observations

Students were observed weekly throughout the semester in the architectural studio, where they participated in the Decathlon Project. The observations occurred during regular studio hours to ensure real-time monitoring of students' activities and interactions. These observations allowed detailed and continuous tracking of students' activity using energy modeling software, design progression, collaboration, and problem-solving as they refined their designs for better building performance results.

Among the six teams working on the Decathlon Project in the studio, the observations primarily focused on the performance team as they refined the design and building performance and collaborated with other teams. The performance team was observed during team meetings, which were held during studio hours, to obtain a better understanding of their contribution to the project. Observations concentrate on how students integrate energy efficiency principles in their designs and how they utilize performance feedback from modeling software to refine them. Student workflow and interactions were strongly monitored to assess how multidisciplinary collaboration influenced decision-making, During observation settings, observations were documented on a Word file, with each note organized by date to indicate when the observation occurred as shown in Appendix C. Notes included primary decisions made during observation settings. Students were not disrupted during observations but were asked for clarifications regarding design and performance adjustments.

3.3.4. Tracking Building Performance

Tracking building performance outcomes helps measure how students applied energy efficiency principles and refined their designs based on performance feedback. Students used two leading software programs, BEopt and Climate Studio, to evaluate building design performance. BEopt software was used to calculate building Source Energy Use (MBtu/yr). The software provides students with an estimation of building total energy consumption, including heating, cooling, lighting, and appliance loads.[36] In addition, Climate Studio was used to measure Daylight performance (sDA & ASE), allowing students to refine passive strategies for improved energy efficiency.

An initial Climate Studio and BEopt baseline assessment established student design reference points. Afterward, students implemented new energy-efficient materials into their design and conducted building performance tests to evaluate impact. Based on performance feedback, students adjusted their design with additional materials to improve efficiency. This procedure was repeated across multiple tests to achieve net-zero energy. After each test, students saved their energy and daylight performance results as PDF files and uploaded them to a shared OneDrive folder on the same day. Once the project was completed, all performance data was transferred to a password-protected computer. The results were organized by type—Source Energy Use and

[36] C Christensen and R Anderson, "BEopt Software for Building Energy Optimization: Features and Capabilities," 11.

Daylight performance—and by chronological order, from earliest to the most recent, for a structured data analysis.

3.4. Data Analysis Methods

Both qualitative and quantitative data, which were collected throughout the semester, were analyzed to assess students' progression in designing prefabricated NZEB. Each dataset was analyzed separately within its subsection to maintain clarity in interpretation and data precision. Data analysis focused on evaluating students' knowledge and confidence growth, finding patterns and trends in students' learning, and examining design performance improvements over time. The following subsections outline the analysis for each dataset, starting with survey analysis, followed by interviews, observations, and lastly, building performance results.

3.4.1. Surveys

Surveys were analyzed in an Excel spreadsheet after being exported from Qualtrics at the end of the semester. Pre-surveys included quantitative and qualitative questions consisting of Likert-scale, ordinal-scale, and open-ended questions. Additionally, post-surveys contained only quantitative questions, consisting of Likert-scale and ordinal-scale questions.

To begin with, quantitative survey responses were evaluated using descriptive comparative analysis. Likert-scale responses were calculated to determine the mean, the median, and the frequency distribution of responses. The mean indicated overall response trends and was calculated by summing all values and dividing by the total number of responses. The median showcased the most typical response and was determined by identifying the middle value after sorting the responses from lowest to highest. Calculated mean and median from pre-survey data were compared to post-survey data. Frequency distribution displayed response count proportions for each category in percentages, calculated by dividing the count of each response category by the total number of responses and converting it into a percentage. Data were visualized using bar graphs, with the X-axis representing Likert-scale values from 0 to 10 and the Y-axis demonstrating response proportions in percentages. Grouped bars were utilized to compare the number of students choosing each rating between pre- and post-surveys. Similarly to Likert-scale questions, ordinal-scale question data were analyzed descriptively by summarizing the responses using proportions of participants choosing each response option in percentages. Bar graphs were utilized to illustrate response proportions, with the X-axis representing response categories (such as confidence and proficiency levels) and the Y-axis displaying the percentages of students selecting each response option. The elevation of each bar reveals the proportion of responses, which were used to compare pre- and post-survey results. The mean and median were calculated for each ordinal-scale question by assigning numerical values from 1 to 5 to response options, and the results were compared to show the central tendency of responses. The descriptive comparative analysis allowed the assessment of changes in students' knowledge, confidence, and familiarity with energy efficiency principles over time.

Following this, qualitative survey questions were evaluated using descriptive thematic analysis. Open-ended survey responses were reviewed to recognize students’ challenges, initial design strategies, experiences, and familiarity with energy efficiency systems. After carefully examining the responses, data were manually coded by grouping similar responses to determine patterns and extract critical findings. Each response was categorized in relation to its central idea to support thematic analysis. In addition, direct quotes from students’ responses were selected to support the critical findings and maintain data authenticity. The summarized findings were then organized by trends and unique perspectives and formatted narratively for discussion.

3.4.2. Interviews

Interview responses were analyzed thematically using Braun and Clarke's six-step approach to reveal patterns in student experiences and learning outcomes. The approach includes six phases of thematic analysis: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming the themes, and writing the report.[37] This approach fits with exploring the rich and complex data collected about student experiences and learning outcomes of NZEB projects.

The first part of the process is to become familiar with the data. After transcribing the interviews, all responses were reviewed multiple times to gather initial thoughts and gradually build a deeper understanding of the data.

The next step is to systematically code the data. Transcribed interviews were uploaded to NVivo 20 software, a qualitative analysis software used to manage and code transcripts, and then were organized by participant response. Relevant excerpts related to the study's focus were highlighted and coded. Custom nodes were then created to represent recurring ideas and then applied to relevant excerpts to group similar responses. These initial codes formed the basis for shaping larger themes that illustrate patterns across the dataset.

After forming initial codes, the next step involved examining the relationships between codes to find themes. Related codes were grouped together based on recognizable patterns that stood out in the data. Next, the grouped codes were categorized into overarching sub-themes and then grouped into broader themes, aligning with the study's context and research objectives. Topics

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[37] Virginia Braun and Victoria Clarke, "Using Thematic Analysis in Psychology," *Qualitative Research in Psychology* 3, no. 2 (January 2006): 77–101, https://doi.org/10.1191/1478088706qp063oa.

that appeared consistently across participant responses were developed into distinct themes and were explored separately.

The fourth step involved reviewing the themes and determining whether they formed a plausible narrative of the student experience in designing NZEBs. Some themes were merged, dropped, or split into subthemes depending on how well they fit the data. The data were revisited to ensure that each theme was sufficiently supported and addressed the interview questions.

Once the themes were finalized, each one was defined clearly and given a specific name. To support the results and discussion, separate tables were created for each theme to illustrate the linked themes, sub-themes, and initial codes. This step ensured that every theme clearly encapsulated its meaning and could be presented in an organized way.

The last step involves writing the report. The result and discussion aim to show how these themes gave insight into student learning and helped explain the challenges and successes of designing prefabricated NZEB.

3.4.3. Observations

Observation data were analyzed chronologically using the dates documented in the Word file to evaluate students' workflow progression throughout the semester. First, each observation entry was categorized under three aspects: collaboration, design modification, and decision-making. Data were then examined to find strategies used, challenges encountered, and critical moments that influenced design performance results. Notes were examined based on the date they were documented, from earliest to latest. Each aspect was analyzed individually first, with respect to the others to understand how collaboration affected students’ perspectives to have design adjustments over time. Lastly, changes in workflow and student engagement were analyzed over time by assessing the dated observation notes in a structured timeline. The data analyzed provides a comprehensive interpretation of students' progress in the project.

3.4.4. Tracking Building Performance

Source Energy Use data were analyzed across nine recorded values, which were visualized in bar graphs. Bar graphs were divided into three panels, each displaying three bar graphs based on chronological order, starting from baseline to iteration 8, for a more precise data interpretation and comparison. The values represent total source energy use (MBtu/yr) over different design iterations. Each bar graph displayed building energy loads, including heating, cooling, and appliance loads. The X-axis represents different design iterations arranged chronologically, whereas the Y-axis represents Source Energy Use (MBtu/yr). Each design iteration was examined by comparing its results with its following iteration, including design modification notes students submitted for each iteration. The comparison allowed the assessment of changes in energy consumption and the impact of design modifications.

Daylight performance was analyzed over three design iterations, each including design modification notes with passive strategies used to evaluate sDA and ASE values. The iterations included two simulation results: one shows daylight autonomy's impact on building design, while the other shows the impact of glare control. Each iteration was analyzed individually alongside its modification notes and compared to the previous one to examine the influence of implemented passive strategies and design refinement on daylight performance. Visual representations created by students, demonstrating passive strategies used, were referenced to enhance interpreting simulation results.

3.5. Ethical Considerations (IRB)

Ethical considerations were prioritized throughout the study, considering that this study involved human subjects and required the recording of verbal responses. To begin with, participants were provided with a clear explanation of the study objectives and data collection process. This includes describing their participation in self-reported pre- and post-surveys, voice-recorded interviews, and weekly observations and will track their building performance data. Students were informed that all information and data collected during the study would remain confidential and stored on a secure computer. Lastly, they were assured their participation was completely voluntary, and they had the right to withdraw at any time without consequences on their coursework or academic status. Each student who agreed to participate was asked to sign a written informed consent form. Additionally, approval from the Institutional Review Board was obtained before collecting data to confirm that the study fulfilled all ethical guidelines and codes of conduct for studies related to human subjects. This study received approval under protocol IRB-12588 from the Kansas State University Institutional Review Board, confirming adherence to ethical guidelines and research integrity as illustrated in Appendix D.

3.6. Chapter Conclusion

The methodology chapter addressed the research design and longitudinal mixed-method approach used to evaluate student learning and design progression in achieving prefabricated NZEB. It explained the study context and detailed data collection and analysis procedures for each method applied to fulfill research objectives. Ethical considerations were addressed, ensuring participant confidentiality and research integrity. This framework offers a structured process for evaluating student learning and design progression through energy efficiency principles to achieve NZEB. The following chapter presents the results and discussion of each method used separately.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0. Chapter Introduction

This chapter presents the study's findings on how students' progression of understanding of energy efficiency concepts influences their ability to achieve prefabricated NZEB design. The results are ordered into four sections: survey responses, interview results, observation notes, and lastly, building performance. Each section introduces the result for a specific method, starting with survey responses, followed by a discussion that interprets the findings separately from other results. Additionally, a brief section is included that illustrates the hands-on building experience, presenting figures of the construction process and materials used in a portion of the building. Lastly, the chapter presents a holistic view of student learning progress and design development over the semester-long project.

4.1. Survey Responses

Each survey question is addressed separately and accompanied by its relevant table and graph. The first survey question included a Likert-scale response, Questions 2 to 7 used an ordinal scale, and Questions 8 to 11 were open-ended and only presented in the pre-survey.

4.1.1. Question 1: Knowledge of Net-Zero

Table 1. Survey Responses for Question 1.

	# Responses		% Responses		Mean		Median	
Response	Pre	Post	Pre	Post	Pre	Post	Pre	Post
3	5	0	22%	0%	5.7	7.8	6	8
4	4	0	17%	0%				
5	1	0	4%	0%				
6	4	3	17%	13%				
7	4	7	17%	30%				
8	3	8	13%	35%				
9	2	2	9%	9%				
10	0	3	0%	13%				
Total	**23**	**23**	**100%**	**100%**				

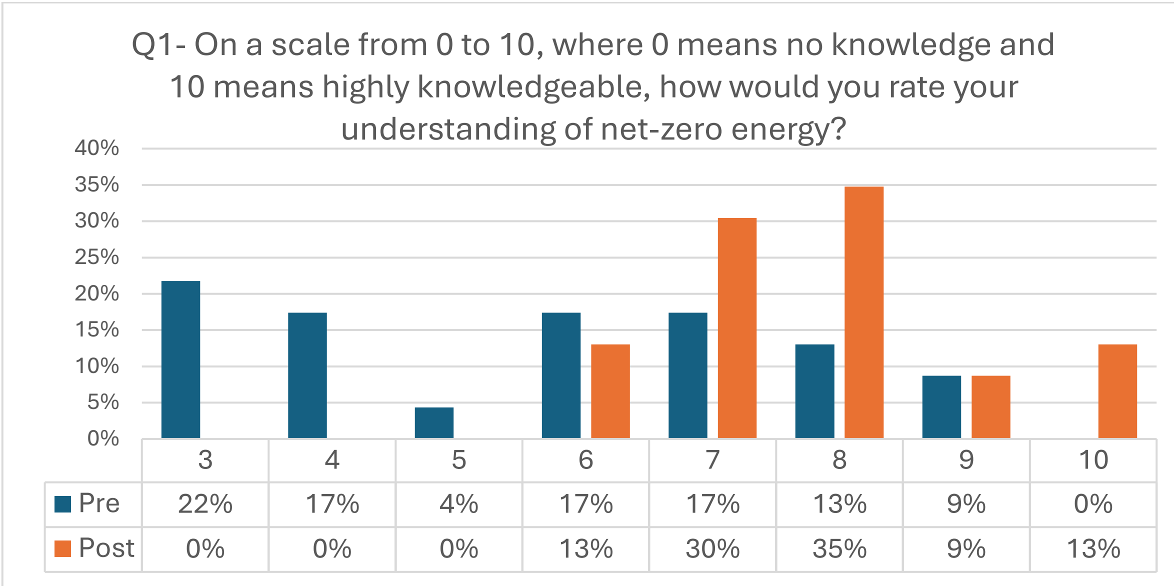

Figure 1. Survey Response Distribution for Question 2.

The first survey question examined student knowledge of net-zero energy on a scale from 0 to 10. As seen in Table 1, pre-survey responses resulted in a mean score of 5.7 and a median of 6. Post-survey responses indicated increased student knowledge, with the mean rising by 2.1 points to 7.8 and the median shifting from 6 to 8. Response proportions are compared in Figure 1, which displays the response percentages for each option in pre- and post-surveys. In the pre-survey, the majority of responses were focused on lower values (3-6). The most selected response was 3 (22%), followed by the most common responses, 4, 6, and 7, each at 17%. Only 9% of students rated their knowledge at 9, while none (0%) selected 10. Conversely, post-survey results altered toward higher values (7-10), with the most common responses being 8 (35%), followed by 7 (30%). The proportion of students selecting 9 remained unchanged at 9% for the post-survey. Notably, no students rated their knowledge below 6 at the end of the semester, and 13% rated themselves at 10.

4.1.2. Question 2: Familiarity with Energy Efficiency

Table 2. Survey Responses for Question 2.

	# Responses		% Responses		Mean		Median	
Response	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Slightly familiar	3	0	13%	0%	3.3	3.9	3	4
Moderately familiar	11	5	48%	22%				
Very familiar	8	15	35%	65%				
Extremely familiar	1	3	4%	13%				
Total	**23**	**23**	**100%**	**100%**				

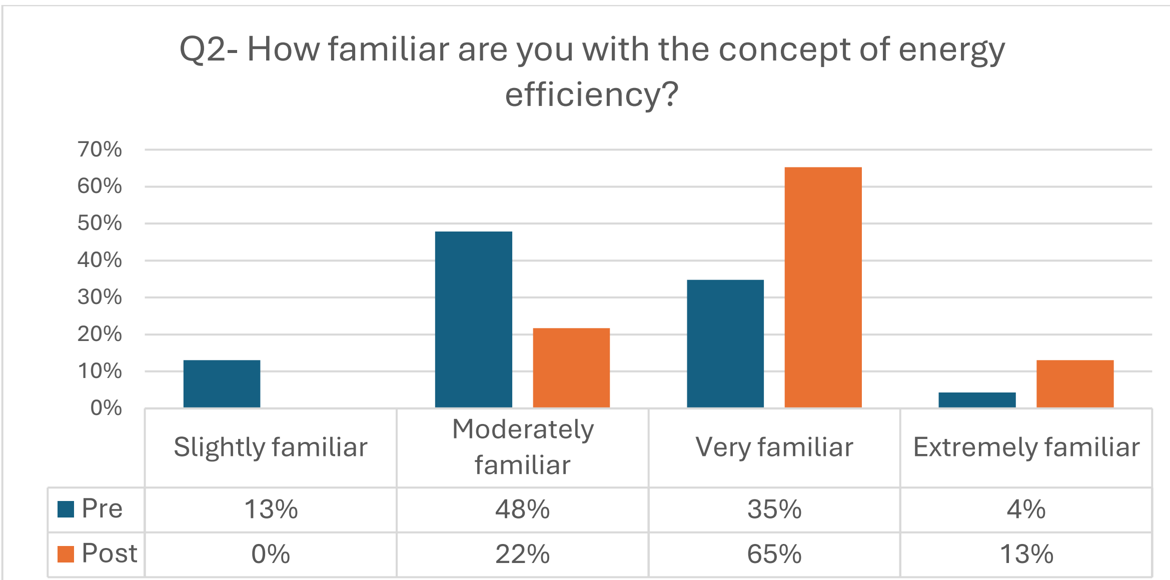

Figure 2. Survey Response Distribution for Question 2.

Question 2 examines student familiarity with energy efficiency concepts. In the pre-survey, as shown in Figure 2, approximately half of the students (48%) described themselves as moderately familiar with energy efficiency concepts. Next, 35% described themselves as very familiar, 13% as slightly familiar, and lastly, only 4% as extremely familiar. In contrast, post-survey responses reveal a significant shift to higher familiarity levels. The proportion of students describing themselves as very familiar with energy efficiency concepts increased from 35% to 65%. Additionally, 22% described themselves as moderately familiar, and 13% as extremely familiar.

Remarkably, no students selected the slightly familiar option in the post-survey. The mean score increased from 3.3 to 3.9, while the median shifted from 3 to 4, as shown in Table 2. In other words, the higher mean score indicates an overall increase in student familiarity with energy efficiency concepts, while the median reflects an upward shift in the most common response.

4.1.3. Question 3: Confidence in Designing NZEB.

Table 3. Survey Responses for Question 3.

	# Responses		% Responses		Mean		Median	
Response	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Not confident at all	4	0	17%	0%	**2.6**	**3.7**	**3**	**4**
Slightly confident	6	0	26%	0%				
Moderately confident	10	9	43%	39%				
Very confident	2	13	9%	57%				
Extremely confident	1	1	4%	4%				
Total	**23**	**23**	**100%**	**100%**				

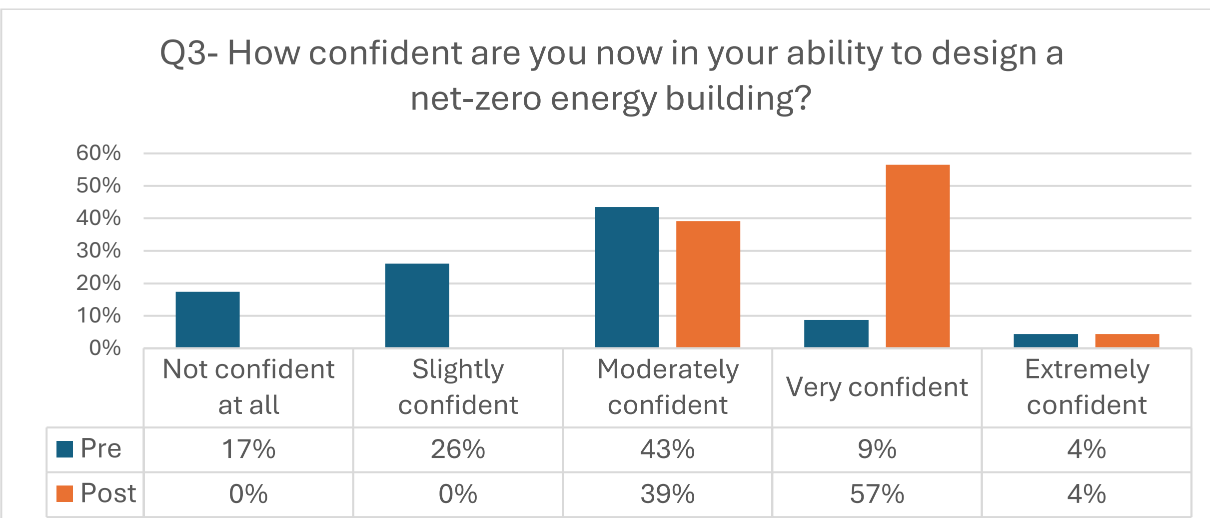

Figure 3. Survey Response Distribution for Question 3.

Question 3 evaluates student confidence levels in designing NZEB, as shown in Table 3 and Figure 3. In the pre-survey, 43% of students described themselves as moderately confident in designing NZEB, making it the most common response selected. Following this, 26% of students rated themselves as slightly confident, 17% reported being not confident at all, and 9%

considered themselves very confident. ‘Extremely confident' was the least selected response, recorded at 4%. In contrast, the post-survey results revealed a crucial shift toward more substantial confidence gains. More than half of students described themselves as very confident, with the proportion increasing from 9% to 57%. Moderately confident responses declined from 43% to 39%, whereas extremely confident responses remained at 4%. Crucially, no students evaluated themselves as “not confident at all” or “slightly confident” in the post-survey. The mean and median confidence scores reflect an overall increase in student confidence in designing NZEB. Table 3 reveals a 1.1 improvement in the mean confidence score, rising from 2.6 to 3.7, while the median rose from 3 to 4.

4.1.4. Question 4: Proficiency in Net-Zero Design

Table 4. Survey Responses for Question 4.

	# Responses		% Responses		Mean		Median	
Response	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Basic proficiency	7	2	30%	9%	**3.3**	**3.3**	**4**	**3**
Intermediate proficiency	4	12	17%	52%				
Advanced proficiency	11	8	48%	35%				
Expert proficiency	1	1	4%	4%				
Total	**23**	**23**	**100%**	**100%**				

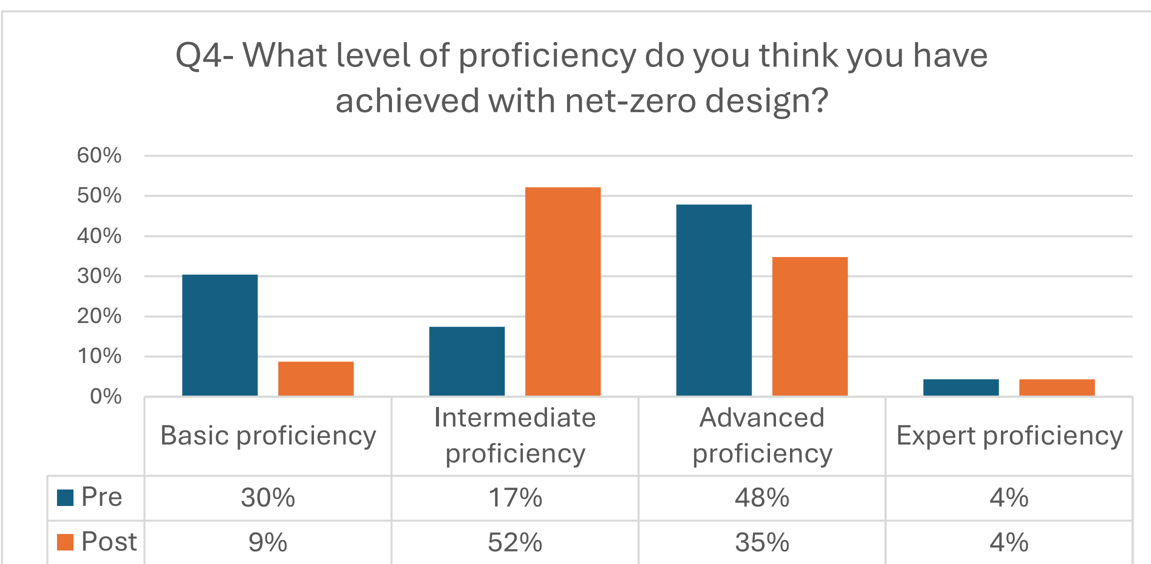

Figure 4. Survey Response Distribution for Question 4.

Question 4 examined student proficiency levels in achieving net-zero design, as illustrated in the self-reported data in Table 4 and Figure 4. Almost half of the students (48%) reported advanced proficiency in the pre-survey. Next, 30% of students selected basic proficiency, 17% considered themselves at the intermediate level, and only 4% indicated they were at the expert proficiency level. Turning to post-survey results, a shift toward intermediate proficiency is evident in Figure 4. More than half of the students (52%) described themselves as having intermediate proficiency levels to achieve net-zero design. Following this, the proportion of students selecting advanced proficiency dropped from 48% to 35%, basic proficiency declined from 30% to 9%, and finally, the proportion of students selecting expert proficiency remained constant at 4%. The mean score showed no change between pre- and post-surveys, while the median declined from 4 to 3, pointing to an overall leaning to lower proficiency.

4.1.5. Question 5: Design Strategy Preference

Table 5. Survey Responses for Question 5.

	# Responses		% Responses	
Response	**Pre**	**Post**	**Pre**	**Post**
Construction materials	7	8	30%	35%
Passive strategies	6	9	26%	39%
Very efficient active strategies	10	6	43%	26%
Total	**23**	**23**	**100%**	**100%**

Question 5 focused on student preferences about the most critical energy efficiency strategies to achieve NZEB. Table 5 and Figure 5 demonstrate that in the pre-survey, the most selected option was very efficient active strategies at 43%. Construction materials were selected by 30% of students, whereas passive strategies had the lowest selection at 26%. Post-survey responses mark a change in preferences, with passive strategies being the most selected option at 39%.

Construction materials increased from 30% to 35%; however, very efficient active strategies declined to 26%, making them the least selected preference among students.

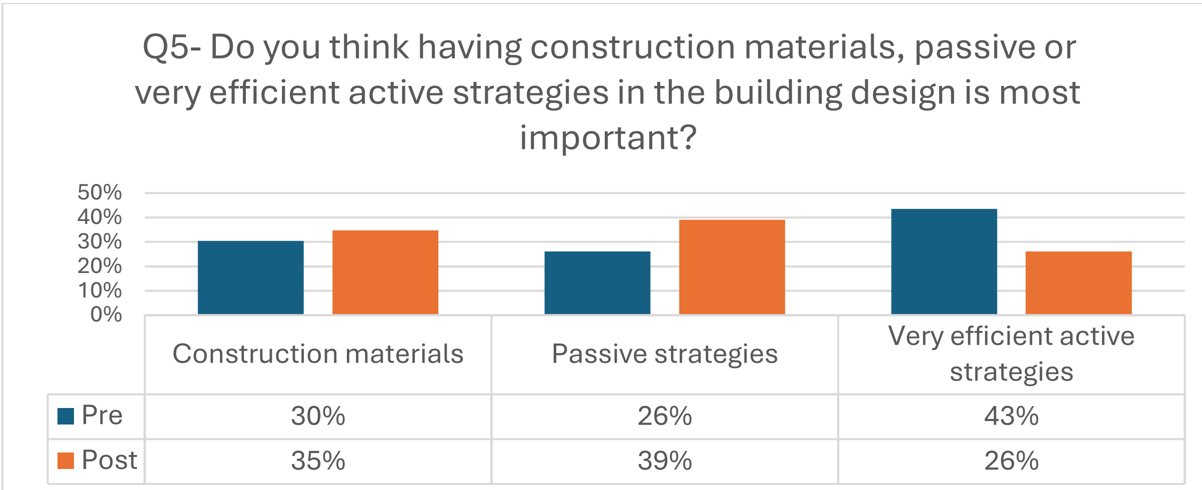

Figure 5. Survey Response Distribution for Question 5.

4.1.6. Question 6: Familiarity with Energy Modeling Tools

Table 6. Survey Responses for Question 6.

	# Responses		% Responses		Mean		Median	
Response	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Not familiar at all	4	0	17%	0%	**2.2**	**3.2**	**2**	**3**
Slightly familiar	13	3	57%	13%				
Moderately familiar	5	13	22%	57%				
Very familiar	0	6	0%	26%				
Extremely familiar	1	1	4%	4%				
Total	**23**	**23**	**100%**	**100%**				

Question 6 assessed student familiarity with energy modeling tools. Based on the results presented in Table 6 and Figure 6, the majority of students (57%) were slightly familiar with energy modeling tools in the pre-survey. Following this, 22% rated themselves as moderately familiar, 17% as not familiar at all, and 4% as extremely familiar. No students considered themselves very familiar with energy modeling tools during the pre-survey. By comparison, post-survey results show an improved level of familiarity, as illustrated in Figure 6. Moderately familiar became the most selected response, rising from 22% to 57% of total responses.

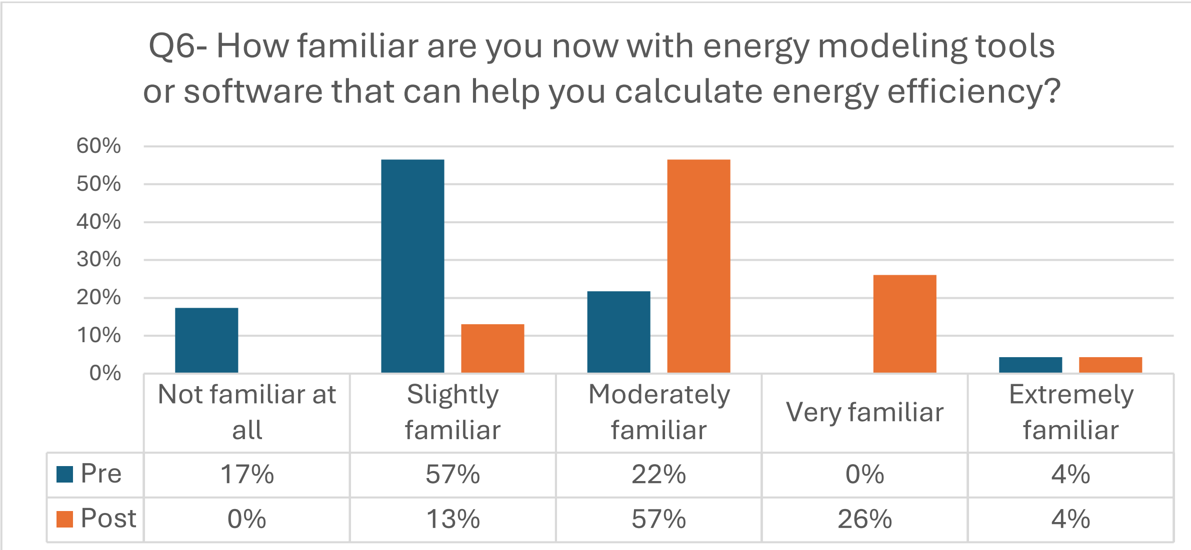

Figure 6. Survey Response Distribution for Question 6.

Moderately familiar became the most selected response, rising from 22% to 57% of total responses. Students describing themselves as very familiar increased from 0% to 26%, while slightly familiar declined from 57% to 13%. Notably, the proportion of students being extremely familiar maintained the same at 4%, and no students reported being not familiar at all in the post-survey. Both the mean score and the median increased between the pre- and post-surveys, rising from 2.2 to 3.2 and 2 to 3, respectively.

4.1.7. Question 7: Importance of NZEB in Future Projects

Table 7. Survey Responses for Question 7.

	# Responses		% Responses		Mean		Median	
Response	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Slightly important	2	1	9%	4%	3.7	4.0	4	4
Moderately important	7	3	30%	13%				
Very important	10	13	43%	57%				
Extremely important	4	6	17%	26%				
Total	**23**	**23**	100%	100%				

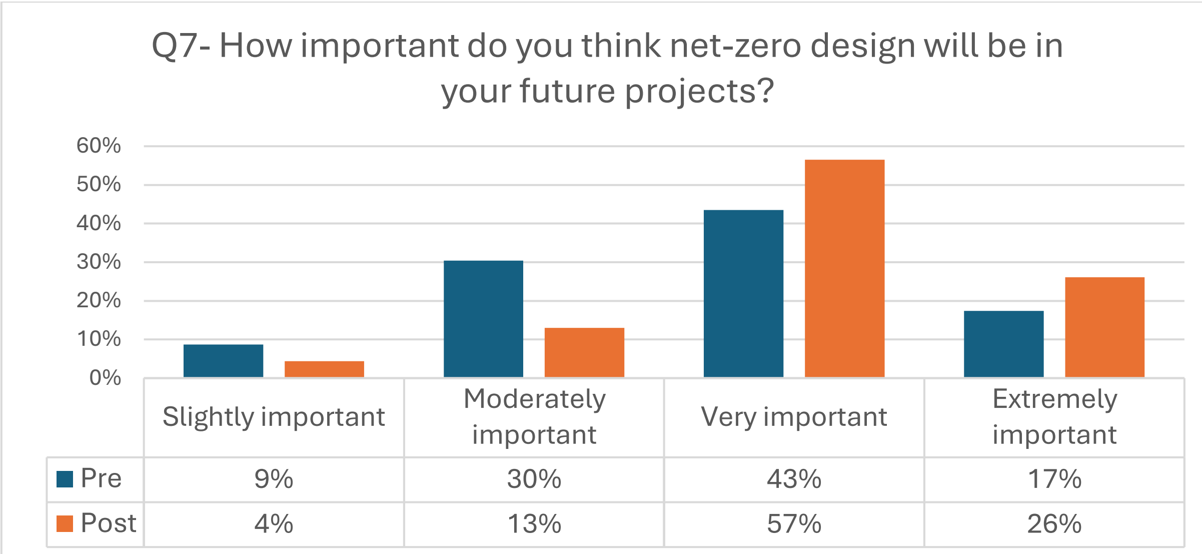

Figure 7. Survey Response Distribution for Question 7.

Student perspectives of NZEB in future projects evolved between pre- and post-surveys, as demonstrated in Table 8 and Figure 8. In pre-survey responses, 43% of respondents considered designing NZEB very important for future projects, followed by moderately important at 30%, extremely important at 17%, and finally, slightly at 9%/ In contrast, more than half of respondents considered designing NZEB very important for future projects in the post-survey, rising from 43% to 57%. The percentage of students selecting extremely important increased from 17% to 26%, while responses for 'moderately important' and 'slightly important' decreased from 30% to 13% and from 9% to 4%, respectively. The change in responses is reflected in the mean score, which rose from 3.7 to 4, whereas the median remained constant at 4.

4.1.8. Question 8: Previous Work in Energy-Efficient Design

Question 8 analyzed whether students had prior experience working on energy-efficient or sustainable design projects. More than half of students (70%) reported not having experience with energy efficiency and sustainability. Based on the responses, 30% of students gained experience either from the Decathlon project studio course in the spring semester or from a course called ESA taught at their school.

4.1.9. Question 9: Challenges in NZEB Design

Several Key challenges were reported by students regarding designing NZEB in Question 9. The first theme focuses on affordability, where approximately 30% of students were concerned with the high expenses of energy-efficient systems, and it could be difficult to maintain affordability while achieving net zero. One student noted, “Everything we have been taught thus far is it's all very expensive to implement and has a long payback period,” highlighting concerns about affordability. The second theme concerns technical challenges, which 25% of students reported. Students mentioned having difficulties in energy production, balancing between different energy ideas, and finding systems that could achieve net zero. Around 20% had concerns with understanding the systems, mentioning having challenges with understanding and finding information about the systems. Notably, a student stated that “HVAC systems don't have a lot of research on how to make them more energy efficient.” The last theme focuses on implementation concerns, identified by approximately 15% of students. Respondents shared their concerns regarding meeting the annual renewable energy demand and forgetting materials that contribute to the energy use of the building. Lastly, around 10% had concerns about net-zero awareness, noting having difficulties explaining net-zero concepts to stakeholders with no energy efficiency background.

4.1.10. Question 10: Initial Strategies for Achieving NZEB

Students reported a variety of initial strategies to achieve NZEB in Question 10. Many have referenced the role of solar energy, with solar panels being the most frequently mentioned strategy to achieve NZEB, followed by rainwater collection and other renewable sources. Others focused on passive strategies, such as natural ventilation, thermal mass, shading, and overhangs to reduce energy demands. Lastly, some responses pointed to the importance of daylighting, material selection, and mechanical systems in enhancing building performance.

4.1.11. Question 11: Familiarity with Energy Efficiency Rating Systems

The last open-ended question assessed student knowledge and familiarity with energy efficiency rating systems. Around 47% of students reported being familiar with at least one energy efficiency rating system, while more than half (53%) were unfamiliar with any rating system. LEED (Leadership in Energy and Environmental Design) was the most frequently cited rating system, followed by HERS (Home Energy Rating System) and Energy Star.

4.2. Survey Discussion

The survey responses demonstrate a significant improvement in student understanding of energy efficiency concepts and the ability to design NZEB. Almost all compared responses from pre- and post-surveys indicated an improvement in overall competence regarding energy efficiency and sustainability. The progress is evident and reflects greater knowledge and familiarity with the overall process.

4.2.1. Question 1: Knowledge of Net-Zero

The first question evaluating student knowledge of net-zero energy shows a considerable increase in the average score from 5.7 to 7.8, with the median rising from 6 to 8. The shift from lower values, 3-6, to higher values, 7-10, in post-survey responses demonstrates a clear improvement in student understanding of net-zero energy concepts over the semester. The fact that no students rated their knowledge below 6 by the end of the semester highlights how much they learned. Additionally, the most selected response jumped from 3 in the pre-survey (22%) to 8 in the post-survey (35%), further emphasizing the evolving of student perceptions over time. This increase reflects the effectiveness of the educational interventions and suggests that students became more confident in their understanding of net-zero energy concepts. Furthermore, the shift towards higher ratings speaks to how students internalized the knowledge, moving beyond superficial familiarity to a more substantial grasp of the material. This improvement indicates that the curriculum addressed knowledge gaps and helped clarify the main concepts.

4.2.2. Question 2: Familiarity with Energy Efficiency

Question 2, which examined familiarity with energy efficiency concepts, demonstrates that the number of students who described themselves as very familiar increased significantly from 35% to 65%. At the same time, the mean score rose from 3.3 to 3.9. No student selected the slightly familiar option in the post-survey, supporting the idea that student familiarity with these concepts grew considerably as a result of instruction and project-based learning. As evidence, practical hands-on experiences and contextual learning were effective in promoting an understanding of energy efficiency. The lack of lower familiarity ratings showcases that the learning process successfully moved students beyond basic awareness to a more nuanced awareness of the material.

4.2.3. Question 3: Confidence in Designing NZEB.

Question 3 focused on confidence in designing NZEB, revealing a substantial gain in student confidence. The proportion of students who considered themselves very confident increased significantly from 9% to 57%, while moderately confident responses decreased slightly from 43% to 39%. This trend indicates that hands-on design exercises and practical applications have improved confidence levels. However, the number of students who rated themselves as extremely confident remained unchanged at 4%, suggesting that, while confidence grew, some students may still feel the need for further practice and experience. The primary implication is that while practical engagement boosts confidence, it may not have entirely alleviated the doubts that students had regarding mastery. Therefore, it may be useful to incorporate additional advanced design challenges or capstone projects to further solidify student learning and self-assessment, which may increase their confidence.

4.2.4. Question 4: Proficiency in Net-Zero Design

The findings in Question 4, which concern proficiency in achieving net-zero design, present a more complex picture. Although the mean score of 3.3 did not change between the pre- and post-surveys, there was a shift from advanced proficiency to intermediate proficiency, going from 48% to 35% and 17% to 52%, respectively. This result may indicate that students developed a more realistic understanding of their abilities and the challenges associated with achieving higher levels of proficiency instead of just making superficial progress. Given this, one may conclude that student exposure to real-world challenges encountered during the course might have propelled students to reassess their initial confidence and readjust their self-assessment. Still, the move toward a more realistic assessment rather than overconfidence is a positive outcome, as it demonstrates critical self-reflection and an honest appraisal of one’s skills.

4.2.5. Question 5: Design Strategy Preference

While 43% of students noted their preference for very efficient active strategies in the pre-survey, passive strategies emerged as the top choice in the post-survey at 39%. This change suggests that students began to recognize the importance of integrating passive strategies to reduce energy demand, reflecting a deeper understanding of energy-efficient design principles. The change in preference aligns with best practices, where passive strategies are prioritized to minimize energy use and enhance thermal comfort before incorporating active systems. It also suggests that students are moving beyond theoretical knowledge and beginning to appreciate the practical benefits of passive strategies for achieving net-zero energy.

4.2.6. Question 6: Familiarity with Energy Modeling Tools

Student familiarity with energy modeling tools, the focus of Question 6, also showed improvement, with the percentage of those describing themselves as moderately familiar increasing from 22% to 57%. The percentage of very familiar responses rose from 0% to 26%. This progress illustrates the positive impact of project-based learning and hands-on experience to improve familiarity with the tools required for NZEB design. The increase in familiarity underscores the value of integrating modeling tools into coursework, enabling students to gain theoretical knowledge and become more competent. Providing opportunities for students to practice using these tools may further improve their confidence and proficiency when they apply them to real-world situations.

4.2.7. Question 7: Importance of NZEB in Future Projects

Question 7 examined student perceptions of the importance of designing NZEBs for future projects. The results indicate a growing awareness of the relevance of NZEBs, with 57% of students rating it as very important in the post-survey, compared to 43% in the pre-survey. Additionally, the percentage of students considering net-zero designs to be extremely important rose from 17% to 26%. These findings suggest that students increasingly recognize the significance of energy efficiency concepts and NZEB in their future professional work.

Recognizing the importance of net-zero design demonstrates how the curriculum successfully conveyed the practical and ethical components of sustainable design. As awareness grows, students may become more motivated to advocate for sustainable practices in their professional lives.

4.2.8. Question 8: Previous Work in Energy-Efficient Design

Question 8 addressed whether students had previous experience in energy-efficient or sustainable design projects. More than half of the students, 70%, reported having experience in this area, which they mostly acquired in the Decathlon project studio course or the ESA course at their school. The high percentage of students with prior experience suggests that many entered the course with prior knowledge, which likely contributed to their rapid progress in understanding energy efficiency concepts. Students with limited or no previous experience may have encountered more challenges in catching up with their peers. Future curriculum planning should consider offering introductory modules or related content to ensure that students without prior experience receive adequate instruction. Finally, taking this step would help reduce disparities in learning outcomes.

4.2.9. Question 9: Challenges in NZEB Design

Question 9 focused on the challenges students faced in designing NZEB. Affordability was the most frequently mentioned challenge, with approximately 30% of students expressing concerns about the high costs associated with energy-efficient systems and their long payback periods. Technical challenges were reported by 25% of students, highlighting difficulties related to energy production, balancing energy systems, and finding effective solutions for achieving net-zero energy. About 20% of students mentioned struggling with understanding complex systems and accessing reliable information. Implementation concerns were raised by around 15% of respondents, who noted difficulties in meeting annual renewable energy demand and overlooking materials that contribute to energy use. A smaller group of students, approximately 10%, reported challenges related to net-zero awareness when explaining concepts to stakeholders with little background knowledge. These findings indicate that while students made progress in understanding net-zero energy concepts, significant obstacles remain in terms of practicality and communication. Lastly, this insight testifies to the need for more focused guidance and instructional support in areas related to cost analysis, technical decision-making, and communication with non-experts. Developing case studies and problem-solving workshops that simulate real-world issues may better prepare students to deal with these challenges.

4.2.10. Question 10: Initial Strategies for Achieving NZEB

Question 10 examined the initial strategies that students undertook to achieve NZEB. The most commonly reported strategy was the use of solar panels, reflecting a preference for renewable energy generation. Other approaches included rainwater collection, passive strategies such as natural ventilation, thermal mass, shading, and daylighting. Some students also emphasized the importance of selecting appropriate construction materials and integrating mechanical systems to improve building performance. The responses suggest that students are aware of various strategies for achieving NZEB and are increasingly focusing on combining active and passive approaches to optimize energy efficiency. The various strategies indicate that students are increasingly recognizing how to attain net-zero goals. By promoting a balanced understanding of active and passive strategies, the curriculum encourages broad thinking and problem-solving.

4.2.11. Question 11: Familiarity with Energy Efficiency Rating Systems

Question 11 assessed students' familiarity with energy efficiency rating systems. Only 47% of students reported being familiar with at least one rating system, while 53% were unfamiliar with any. The lack of familiarity with rating systems indicates a potential gap in student knowledge that could hinder the ability to apply energy efficiency concepts in real-world projects to design NZEBs. Incorporating more instruction on energy efficiency rating systems may sharpen student readiness to design buildings that meet recognized standards of sustainability and efficiency. To address this gap, future courses should incorporate instruction that deals directly with rating systems, including practical exercises that require students to evaluate and design projects to meet specific rating criteria.

4.3. Interview Results

Interview responses revealed a range of perspectives on student learning experiences. The findings were organized into five overarching themes: learning energy efficiency through a real-world project, challenges with energy concepts, design decisions, tool use, and interdisciplinary collaboration. Each theme encapsulates a distinct area of student experience, whereas the sub-themes reflect more specific topics and patterns. The resulting thematic structure is illustrated in a series of tables, where each theme is paired with its sub-themes, relevant initial codes, number of participants contributing to the theme, and number of excerpts assigned to the theme.

4.3.1. Theme 1: Learning Energy Efficiency Through a Real-World Project

Table 8. Interviews Theme 1

Theme	Sub-themes	Initial Codes	No. of participants	No. of excerpts

			contributed to the theme	assigned to the theme
Learning Energy Efficiency Through a Real-World Project	Initial Knowledge and Awareness	Limited familiarity with energy strategies	8	10
		Self-rated understanding	7	7
		Sources of prior knowledge	8	9
	Conceptual vs. Theoretical Learning	Real-world application	9	9
		Impact of minor design changes	5	5
		Understanding of energy efficiency	4	5
		Increased awareness of materiality and insulation	5	5

The first theme emphasized how real-world project-based learning promotes deeper understanding through hands-on and conceptual experiences. The sub-themes revealed that working on a project in a real-world setting significantly improves student knowledge. Drawing from the interview results, students began the project with varying levels of prior knowledge of energy efficiency concepts. Most rated their understanding as limited and said it was based on a single previous course. All participants highlighted an improvement in their knowledge over the semester, which they associated with the fact that the project would actually be built. Nearly all students expressed concern over every design detail, knowing that any mistake would affect a real building rather than a simulated one. These concerns increased their awareness of materiality and insulation, which they noted would not have happened in a theoretical studio course.

4.3.2. Theme 2: Challenges in Understanding and Applying Energy Efficiency Concepts

Table 9. Interviews Theme 2

Theme	Sub-themes	Initial Codes	No. of participants contributed to the theme	No. of excerpts assigned to the theme
Challenges in Understanding and Applying Energy Efficiency Concepts	Studio Hours Challenges	Conflicting feedback from professors and experts	2	2
		Interdisciplinary collaboration challenges	5	11
	Obstacles in the Design Process	Difficulty in data interpretation	5	5
		Iterative modifications	3	4
		Passive strategy confusion	4	4
		Thermal insulation complexity	6	7
		Material selection difficulty	5	9

The second theme focused on the challenges students faced during their design process over the semester. As shown in Table 9, the sub-themes underscored difficulties with technical concepts, such as thermal insulation, material selection, and data interpretation. Based on interview results, several reported being confused by receiving different feedback from professors, which made it difficult to decide which design direction to follow. This contributed to an extensive design iteration instigated over the semester and caused delays in project development and decision-making. Participants explained that each design change was passed from one team to another, with the performance team being the last to receive it for energy and daylight analysis. This process, they noted, often took several days and left some teams inactive while waiting for the updated design. Following this, some students struggled with passive strategies and had to learn about them in the middle of the design process, which caused additional delays in updating the design.

4.3.3. Theme 3: Design Decisions and Their Impact on Energy Efficiency

Table 10. Interviews Theme 3

Theme	**Sub-themes**	**Initial Codes**	**No. of participants contributed to the theme**	**No. of excerpts assigned to the theme**
Design Decisions and Their Impact on Energy Efficiency	Feedback-Driven Changes	Design adjustments	5	5
		Material selection updates	3	4
	Passive Strategies	Window placement	4	5
		Continuous insulation	5	9

		Cross-ventilation	5	6
		Building orientation	2	3
		Implementation of shading devices	4	4

This theme examined critical design decisions, including the use of passive strategies and feedback adjustments from tools, professors, and peers, with sub-themes underscoring their importance in enhancing energy performance. Participants discussed how feedback influenced material choices and led to design adjustments that improved aspects such as insulation, ventilation, and window placement. Many explained that they started by implementing basic passive strategies early in the design process. After noticing their positive impact on performance, they added more, learning how each would improve the overall building performance.

4.3.4. Theme 4: Using Performance Modeling Tools in Design Learning

Table 11. Interviews Theme 4

Theme	Sub-themes	Initial Codes	No. of participants contributed to the theme	No. of excerpts assigned to the theme
Using Performance Modeling Tools in Design Learning	Building Performance Tools and Design	BEopt for energy performance	2	2
		Climate Consultant	2	3

		Climate Studio for daylight performance	3	5
	Software Challenges	Engineers leading analysis	2	2
		Limited tool familiarity	3	4

This theme examined how the use of performance modeling tools enabled students to learn more about the relationship between design decisions and energy performance. Students mentioned using tools like BEopt and Climate Studio to test how different materials and energy efficiency strategies influenced building performance, including energy use and daylighting. Many said these tools helped them better understand energy efficiency by making the results of their design choices more visible. Some students struggled with unfamiliar software or relied on engineering teammates to interpret the results. Even so, most felt that using these tools improved their understanding of energy principles and net-zero goals and offered a real-world perspective on designing for energy performance.

4.3.5. Theme 5: Effective Collaboration between Architects and Engineers

Table 12. Interviews Theme 5

Theme	**Sub-themes**	**Initial Codes**	**No. of participants contributed to the theme**	**No. of excerpts assigned to the theme**

Effective Collaboration between Architects and Engineers	Collaborative Learning Experience	Joint Decision Making	2	2
		Communication and Coordination	2	3
		Interdisciplinary teamwork	3	5
	Knowledge Sharing and Cross-Disciplinary Learning	Varying expertise levels	2	2
		Mutual Knowledge Exchange	3	4
		Bridging Disciplinary Gaps	2	2

The last theme explored the collaborative relationship between architects and engineers, both of whom served important roles during the design process. The collaboration enabled possibilities for knowledge exchange between disciplines, such as engineers explaining BEopt to architecture students or working with the systems team to understand how their materials impacted design performance. Participants noted that material selections were made collaboratively, with consideration for energy efficiency, cost, and aesthetics. The collaboration also helped architecture and engineering students overcome challenges by allowing them to better understand each other's perspectives.

4.4. Interviews Discussion

The discussion section provides insights into the identified results in terms of themes in the previous section. The organization of this section is based upon the discussion of themes along with their explanation and supporting quotes of participants to strengthen the outcomes.

4.4.1. Theme 1: Learning Energy Efficiency Through a Real-World Project

Working in a real-world setting, rather than a traditional studio course, led many students to approach their design decisions more carefully, mainly because they knew the project would actually be built. One student shared: *"It made me put a lot more thought into it"* (Participant 2), which reveals a shift of student perspectives since they knew their work would contribute to an actual building, where design mistakes could have real consequences. The project offered a learning experience that is not typically found in traditional coursework, which enhanced their understanding of building performance and sustainability. As Participant 10 noted, *"Actually, building the thing has taught me so many things that I would not know if we weren't building it, even just simple framing."* The stronger attention to material selection indicates that this learning process strengthens concepts that are often missed in traditional courses. These findings align with the study objectives as they reveal the improvement of student knowledge through a real-world project.

4.4.2. Theme 2: Challenges in Understanding and Applying Energy Efficiency Concepts

The findings highlight challenges students encountered while designing NZEB in a real-world environment. Many students struggled with how certain design strategies function in practice, as one participant shared, "*Probably thermal installation and how to block unwanted heat or cool air*" (Participant 1). Another student added on this challenge, stating, "*I would say probably just the connections between the floor, the wall, and then the wall and the roof… because those are* *the points where air tends to get in the most or the weakest points of a building*" (Participant 9). Even with a general understanding of insulation strategies, students still faced uncertainty when applying them to complex connection points in the building envelope.

Design progress was also slowed by difficulties in interpreting performance data, which several students described as hard to access and understand. Participant 3 mentioned that "*some of the data was a little hard to find,*" which made it difficult to achieve net-zero energy. Material selection was another challenge students faced during the design process. As Participant 2 mentioned, "*Not realizing exactly how all the materials worked and how to choose them.*" This lack of knowledge made the use of Climate Studio challenging since they didn't have all the information needed to test building performance.

Collaboration became more difficult as team sizes increased, which complicated the process of keeping everyone in agreement on decisions. One student explained that while early collaboration was coordinated, "*as the group got bigger... it was harder to keep your line of communication and have everyone on the same page about everything"* (Participant 5). In some cases, students with prior experience expressed frustration at having to explain to their peers that design decisions needed to meet real building codes and construction standards, which is often overlooked in theoretical studio projects but critical in a real-world build. Participant 7 described the challenge of working with less experienced peers, saying it involved "*having to explain to them, yes, we need to follow code or like we can't just ignore this small piece that we usually can in these theoretical projects because this is actually getting built."* Lack of clarity during group decision-making was one of the most significant collaboration challenges that slowed down the design process. One student put it clearly: "*It was a little hard getting those final decisions. There was just so much back and forth, it's like, can you just make a decision already?"*

(Participant 10). These reflections uncover how challenges in a collaborative environment can complicate communication among students, causing frustration and, hence, delaying design progress.

4.4.3. Theme 3: Design Decisions and Their Impact on Energy Efficiency

Many students noted that they adjusted their design based on feedback from professors, peers, or simulation tools to meet net-zero energy. This reveals the effectiveness of feedback-driven changes on developing their understanding from being theoretical to a more applied approach. One student, for example, said, "*The HVAC equipment changed a few times... it had more capacity than it needed*" (Participant 3), which pointed to how their decisions moved toward being more performance-focused over time. Another student mentioned that meeting with a professor outside their studio course led to changes in the foundation design: *"We also had to go meet with Gibson to get a lot more feedback from him since he's made passive designs before… the foundation is something that changed a lot"* (Participant 5). Feedback not only guided decisions but helped students make choices that enhanced energy efficiency.

In parallel, students made thoughtful use of passive strategies across design iterations to enhance energy efficiency. Insulation was considered a crucial building material among students and recognized as a key passive strategy. Participant 6 stressed its importance, explaining: *"The major design decision was definitely to use the exterior insulation and try to make that continuous,"* and another reflected, *"I think the continuous insulation around the whole building set us on a good path from the beginning"* (Participant 5). Another major consideration was window placement, as shared by Participant 2: *"I remember I put in the building, and with certain windows, the energy efficiency plummeted to nothing. And it's crazy how the whole wall was completely energy efficient, but just the wrong window changed the statistics completely."*

Rather than seeing it as just a design feature, students learned through the design process to think critically about how window placement affects overall building performance. This was also noted by Participant 3: *"Window placements changed a lot,"* which reveals the efforts of increasing daylight and lowering cooling needs for better performance results. The fact that window placement was changed substantially based on performance feedback illustrates the development of their understanding of passive strategies. In short, these design decisions demonstrate how students applied energy-efficient concepts in more purposeful ways to support energy performance.

4.4.4. Theme 4: Using Performance Modeling Tools in Design Learning

Performance tools offered students an opportunity to measure, adjust, and validate their design strategies using real-time data. BEopt, for example, helped with iterative testing and visualization of energy use. Participant 3 reflected, *"I do think that it provides good feedback by showing graphically what different changes do to the energy usage,"* and another noted, *"The graphs from Climate Studio and BEopt were really nice to see how our design decisions were improving or reducing the energy efficiency"* (Participant 4). This suggests that the visualizations from these tools helped them gain more knowledge about the effects of implemented materials and their contribution to building performance. However, software challenges arose, such as limited expertise with BEopt. As one participant noted, *"Only the engineers knew how to use BEopt"* (Participant 7), which obscured its use. Limited familiarity restricted access to the tool and drew focus on the need for more students to develop proficiency with it. This contributed to delays in testing different iterations, given its role in evaluating and distributing energy performance across the design. Despite these challenges, the tools supported students in applying energy efficiency concepts in real-world design contexts.

4.4.5. Theme 5: Effective Collaboration between Architects and Engineers

Collaboration between architecture and engineering students played an important role in shaping both the design outcomes and how students learned throughout the process. For many, it provided a chance to gain and exchange knowledge, notably when dealing with unfamiliar systems and understanding how they affected building performance. Participant 7 shared their experience*: "The most challenging to understand is from an architecture perspective, how all of the mechanical systems are working… But then once the engineering students explained it and like showed how that works and how they can work differently, it was actually really interesting."* That peer-to-peer exchange brought a different level of understanding and helped share knowledge and information between students with different educational backgrounds. Another student mentioned how this dynamic helped with technical decisions: *"I think the collaboration was helpful… I was having issues with materiality and things… the envelope team… helped me get exact measurements of everything"* (Participant 2). Participant 3 described how design development occurred among different teams, noting, *"We used the design team to create our baseline model... The envelope team, we worked with them a lot to make sure that the building was insulated... And then the systems team... They need to make the building function."* These takeaways illustrate how significant interdependent team roles were and how successful energy performance depended on collaborative efforts across all disciplines.

4.5. Observation Notes Results

Improving the building's daylighting, thermal performance, and energy efficiency first required drafting the foundational documents and setting appropriate goals, which occurred in late September and early October 2024. Initial preparations involved creating the Studio Performance Research File on September 30, and then, on October 2, setting up the Energy Performance team structure and outlining goals. With this preparation complete, it was possible to move forward with the analytical modeling and performance assessments. By October 14, a preliminary model was designed using Rhino for Climate Studio. An energy efficiency research document was uploaded to OneDrive, and baseline results were generated using BEopt, establishing energy performance metrics.

The first significant analysis occurred on October 16, when the completed Climate Studio model was thermally evaluated. This initial assessment established a basic understanding of the model's performance. Daylight analysis was conducted at 9:00 AM and 3:00 PM using Climate Studio, resulting in an average illuminance of 3067 lux. Performed with double-glazed windows, this assessment yielded a Spatial Daylight Autonomy (sDA) of 30.6% and Annual Sunlight Exposure (ASE) of 28.7% through the collaboration of envelope and performance teams. The materials were also analyzed in BEopt under a new design iteration, which generated updated Source Energy Use data. Recognizing the issue of excessive daylight, the model was refined by the design team on October 23. Some of the refinements included reducing the windows from 3x6 to 2x4, adding overhang shading, and upgrading the window glazing to triple-glaze. The last modification reduced average lux by approximately 100, allowing for greater control over the interior light. At the same time, the design team provided multiple layers for the building envelope, which were added to the model. The performance team tested a new design iteration in BEopt based on the new refinements from the design and envelope teams.

During this phase, high relative humidity ratios needed to be addressed. Working with HVAC specialists helped decrease tonnage requirements while a builder from Saint Louis was consulted to review the baseline model's HERS index. Solar panels were designed even though their input was not integrated into BEopt. The Design team shared a refined model that noted the updated window sizes and placements with the Performance team to test its effectiveness in building performance. Additional adjustments occurred on October 28. The Systems team addressed a clearance issue with the heat pump unit that did not impact energy results but could have led to possible performance delays. While this occurred, the Performance team revised its daylight analysis according to the window sizes and overhang depths, which were calculated using the P = H/F (Projection = Glazed Opening Height / Factor Based on Latitude) formula.

The iterative process reached a critical point on October 30, when the design team introduced polycarbonate walls to replace previous slab walls to improve insulation performance. The mechanical room was expanded after the collaboration between the engineers in the Systems team and the architects in the Design and Performance teams to address the heat pump clearance problem. The Performance team received the new design adjustment that included the heat pump and tested it using BEopt. Passive strategies were refined using Climate Consultant Software, which considered local weather data and psychrometric charts. Polycarbonate wall thickness was assessed multiple times through collaboration between the performance and design teams for efficiency before finalization. However, delays in material uploads prevented the performance team from continuing its thermal analysis. The delay was caused by the design team due to the continuous design refinement, which resulted in other teams waiting until they received the new adjusted design. Research on Saint Louis climate data guided the use of cross ventilation, operable windows, and green walls in the model. Diagrams showing sun-path, shading, ventilation, and green walls were created to demonstrate the effectiveness of these strategies and are displayed in section 4.5.1. Source Energy Use results from BEopt were illustrated using bar graphs arranged chronologically, from baseline design to iteration 8, with detailed notes alongside each iteration. The final daylight analysis and BEopt results, with detailed notes, were saved to OneDrive.

4.5.1. Passive Strategies Diagrams

Students created passive strategies diagrams on October 30th to help visualize the implemented passive strategies in the design. These diagrams aimed to help both the students and the stakeholders, allowing them to refine the design based on the improved knowledge of the strategies and provide a better understanding to stakeholders.

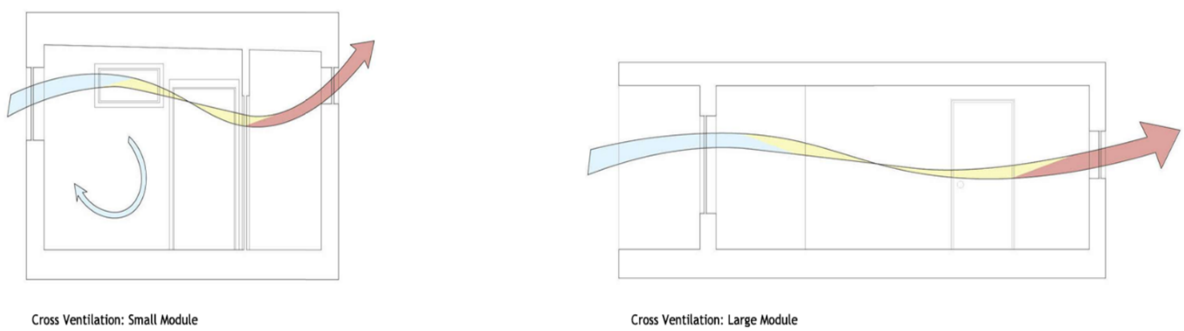

Figure 8. Cross Ventilation

Figure 9. Sun Shading and Green Wall Diagrams

4.6. Observations Discussion

Documenting the structure and undertaking the appropriate modeling and analysis yielded useful insight into the building's daylighting and thermal performance. From the start, the Energy Performance team demonstrated strong analysis, and the use of generic materials during the initial assessment stage provided a useful understanding of the building's baseline performance. In addition, the October 16 findings reflected issues related to excessive daylight exposure, which the high lux levels and substantial ASE showcase. The adjustments made in the different iterations helped reduce the average lux by approximately 100, mostly due to the changes in window sizes and the triple-glaze. Finally, the shading devices provided greater control, improving the model's daylight autonomy. These design iterations reveal the improvement of student knowledge regarding energy efficiency concepts, where they tested different iterations to solve excessive daylight exposure.

Creating the building envelope by October 23—including roof, wall, and floor components—illustrates the desire to improve thermal efficiency. However, humidity control issues revealed limitations in the model's inputs. Reducing VAC tonnage and reviewing the HERS index reveals the need to simulate real-world mechanical systems accurately. Meanwhile, increasing energy use according to more precise HVAC and hot water input integration reflects the difficulties associated with balancing thermal performance with energy consumption predictions. This result speaks to the need for consistent coordination when designing and building relevant models.

A major factor contributing to the project's progress was the collaboration between different teams, particularly that between the Performance team, Systems team, and Design team. Architects and engineers routinely communicated with each other to address various challenges, including clearance issues with the heat pump unit and the introduction of polycarbonate walls to improve insulation. This interdisciplinary cooperation eased the design process and ensured that other teams quickly evaluated and integrated the changes that another made. The collaboration allowed for simultaneous adjustments in thermal performance, structural design, and mechanical systems, making for a successful project.

The project also benefited from ongoing communication and file sharing via platforms like OneDrive, which enabled the exchange of performance analysis results, diagrams, and models. The clear division of responsibilities, combined with a shared understanding of project goals, helped reduce the likelihood of any delays and led to better decision-making. However, delays related to continuous design improvements that the Design team undertook still arose, reflecting the need for improved coordination strategies. Effective communication between architects and engineers remains vital to overcome these challenges and meet project objectives.

4.7. Tracking Building Performance Results

This section includes data results for Source Energy Use and daylight performance (SDA and ASE). Each data result is presented separately, and a discussion section will combine both results to connect the daylight performance results to overall energy use outcomes.

4.7.1. Source Energy Use

Students performed nine Source Energy Use tests, as displayed in Figure 10, starting from baseline to iteration 8. Each design iteration included modification notes that assessed the performance outcomes. The results are divided into three panels to better visualize and compare the results.

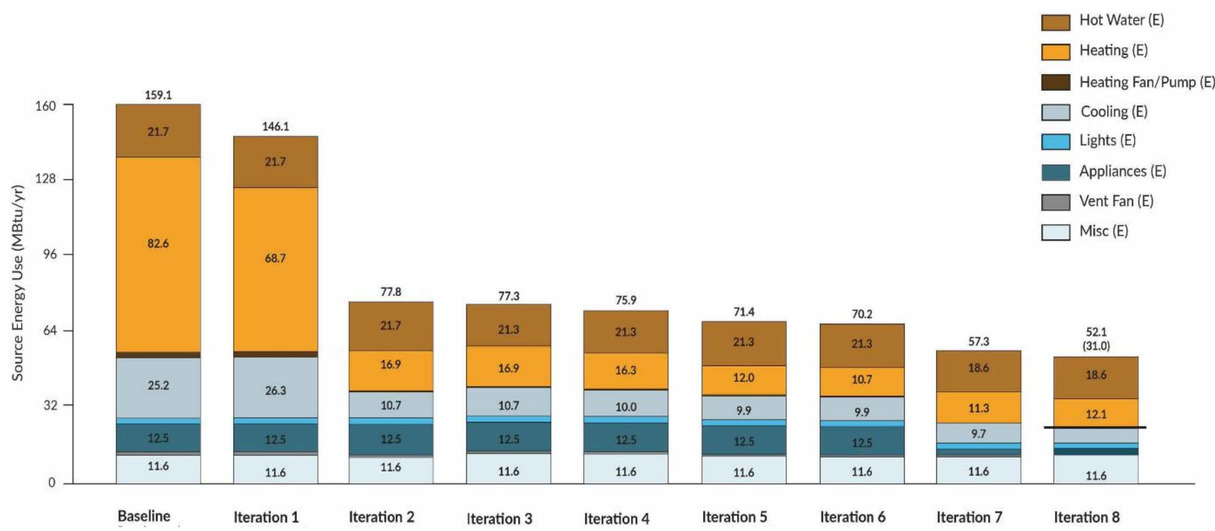

Figure 10. Source Energy Use Results

4.7.2. Baseline to Iteration 2

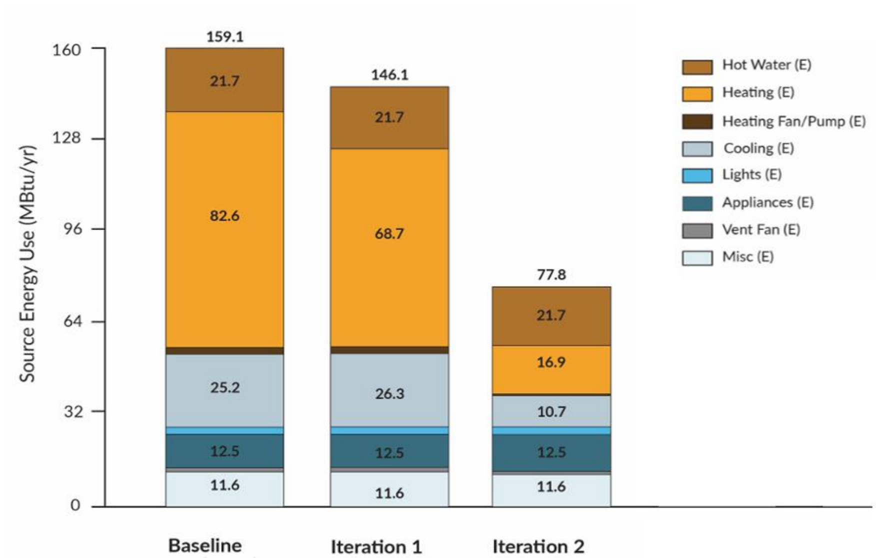

Figure 11. Source Energy Use First Graph Panel

The baseline model shows a total energy use of 159.1 MBtu/yr, with heating accounting for 82.6 MBtu/yr, making it the largest contributor. Hot water energy use is 21.7 MBtu/yr, and cooling energy use is 25.2 MBtu/yr. The model included assumed materials; however, it served as a starting point for implementing building components and energy efficiency strategies.

Iteration 1 reduces total energy use to 146.1 MBtu/yr, primarily by lowering heating energy to 68.7 MBtu/yr. This improvement is achieved through changes to the building envelope: wall construction was changed to 2x6 stud framing with R26 batt insulation, and roof construction was changed to 2x12 with R49 batt insulation. Cooling energy use slightly increases from 25.2 MBtu/yr to 26.3 MBtu/yr, reflecting potential changes due to improved insulation.

In Iteration 2, total energy use drops to 77.8 MBtu/yr. The most significant changes are in heating and cooling energy, which decreased from 68.7 MBtu/yr to 16.9 MBtu/yr and from 26.3 MBtu/yr to 10.7 MBtu/yr, respectively. This reduction results from replacing the heating system with an electric tank furnace combined with a window unit for air conditioning, as well as specifying a ducted mini-split system. This iteration shows how upgrading HVAC systems and greater energy efficiency can reduce heating and cooling energy demands.

4.7.3. Iteration 3 to Iteration 5

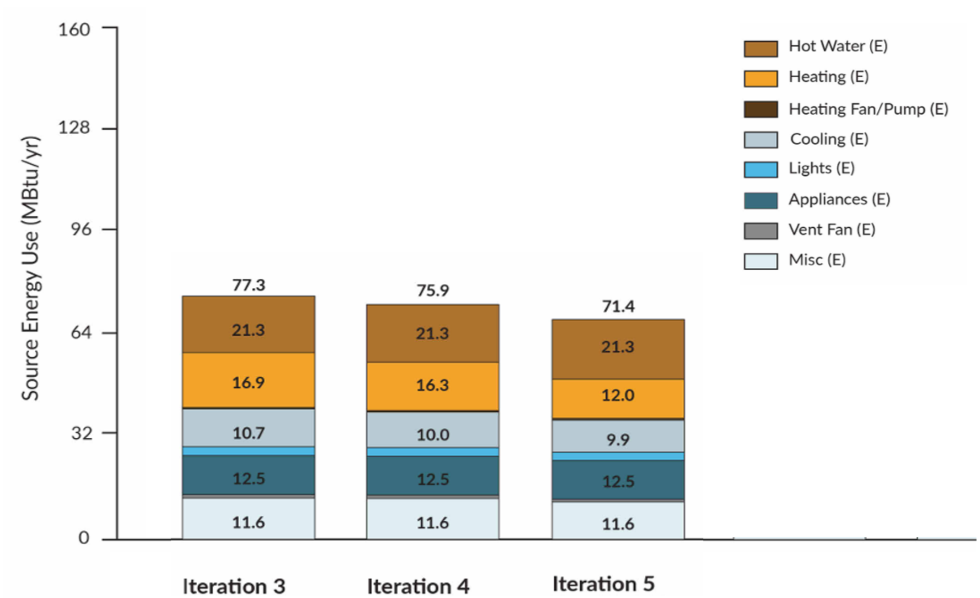

Figure 12. Source Energy Use Second Graph Panel

Iteration 3 slightly lowers the total energy use to 77.3 MBtu/yr. The most noticeable change is a small decrease in hot water energy use from 21.7 MBtu/yr to 21.3 MBtu/yr. This improvement results from switching electric tank-style water heaters to point-of-use (POU) water heaters, which the engineers in the systems team provided. POU water heaters reduce energy waste by heating water closer to the point of use rather than storing it in a central tank. Cooling and heating energy use remains stable at 10.7 MBtu/yr and 16.9 MBtu/yr, respectively.

Iteration 4 reduces total energy use to 75.9 MBtu/yr by targeting the efficiency of windows. The window type was changed to one with a lower U-value, and window placements were reconfigured to better align with sun pathing, resulting in a modest decrease in heating energy use from 16.9 MBtu/yr to 16.3 MBtu/yr. Cooling energy is also reduced slightly from 10.7 MBtu/yr to 10.0 MBtu/yr as better window placement minimizes solar heat gain.

In Iteration 5, the focus is on slab insulation provided by the envelope team. The slab construction was updated to R40 insulation, similar to the roof construction. This change reduces heating energy to 12.0 MBtu/yr, and the total energy use decreases to 71.4 MBtu/yr. It also decreased cooling energy by only 0.1 MBtu/yr, bringing it to 9.9 MBtu/yr. Improved slab insulation leads to greater thermal efficiency in the building envelope, consistent indoor temperatures, and reduced demand for heating.

4.7.4. Iteration 6 to Iteration 8

Iteration 6 focuses on reducing equipment loads by relaxing setpoints, which allows for the selection of smaller, more efficient equipment. Additionally, duct specifications were adjusted as layouts changed. These improvements reduced heating energy from 12.0 MBtu/yr to 10.7 MBtu/yr, resulting in a total energy use of 70.2 MBtu/yr, as shown in Figure 13.

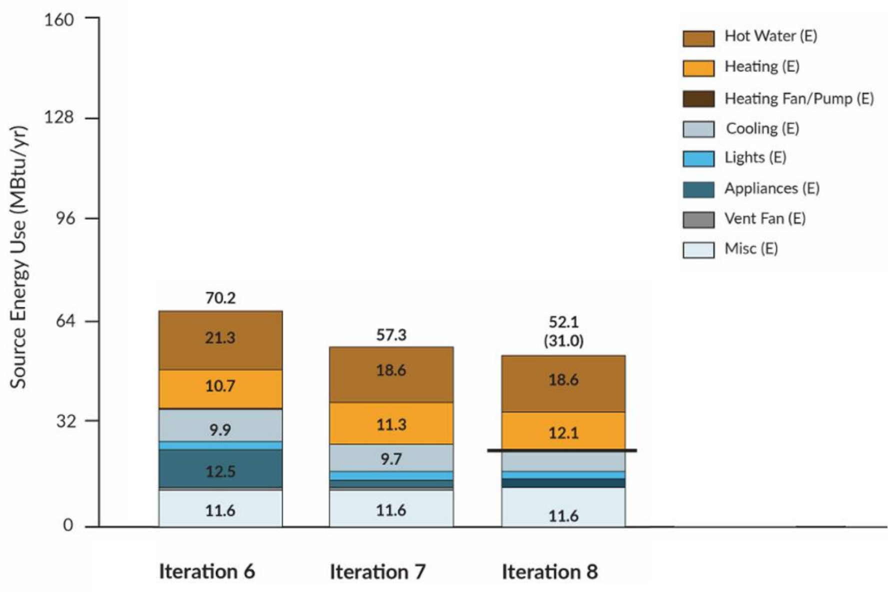

Figure 13. Source Energy Use Third Graph Panel

Iteration 7 implements updated appliance information, including refrigerators, cooking ranges, dishwashers, and clothes washers. As a result, hot water energy use drops from 21.3 MBtu/yr to 18.6 MBtu/yr due to more efficient water heating systems. Cooling energy also decreases slightly from 9.9 MBtu/yr to 9.7 MBtu/yr. However, heating energy shows a slight increase to 11.3 MBtu/yr, potentially due to appliance heat outputs contributing to the indoor environment. The total energy use decreases significantly to 57.3 MBtu/yr, indicating the impact of energy-efficient appliances.

The final iteration, Iteration 8, represents the culmination of all improvements. The total source energy use dropped by 5.2 MBtu/yr, bringing it to 52.1 MBtu/yr. In this iteration, specific categories were recalculated for efficiency and reflected an increase in recorded heating energy from 11.3 MBtu/yr to 12.1 MBtu/yr. Hot water energy remains consistent with the previous iteration at 18.6 MBtu/yr. Comparing the finalized source energy use outcome with iteration 1, energy use decreased by a total of 94 MBtu/yr throughout all design iterations.

4.7.5. Daylight Performance Results

The daylight analysis sought to improve Spatial Daylight Autonomy (SDA) and reduce Annual Sunlight Exposure (ASE), relying on passive strategies in various iterations to do so. The process focused on improving daylight performance while minimizing glare and ensuring thermal comfort.

4.7.6. Daylight Performance Iteration 1

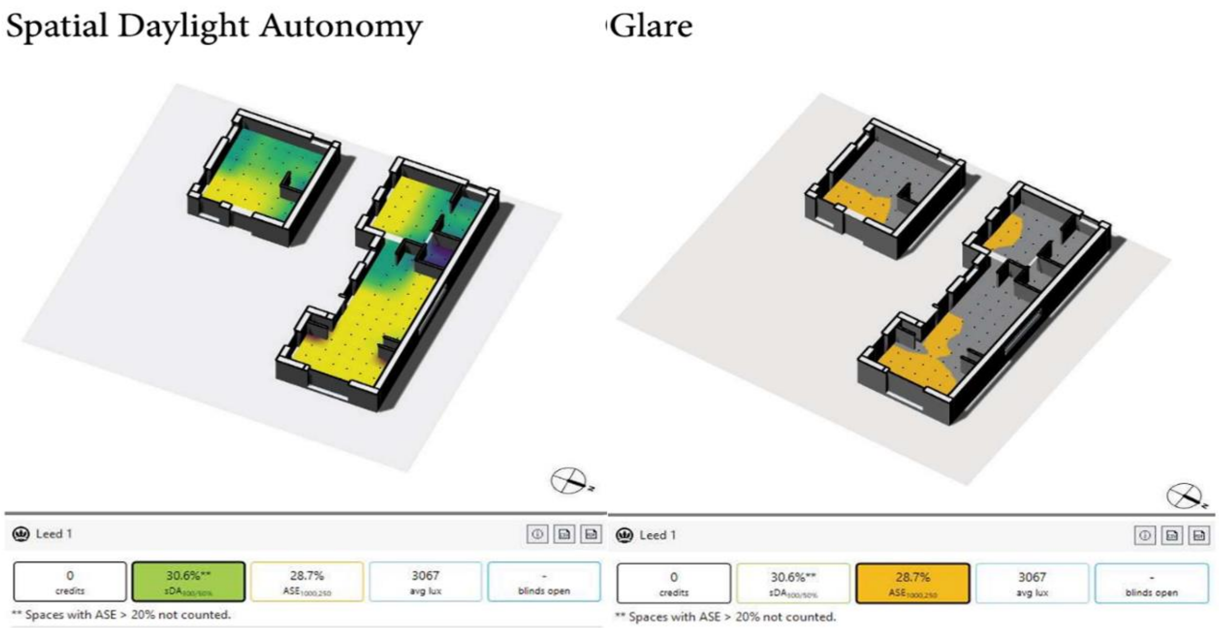

Figure 14. sDA and ASE Iteration 1

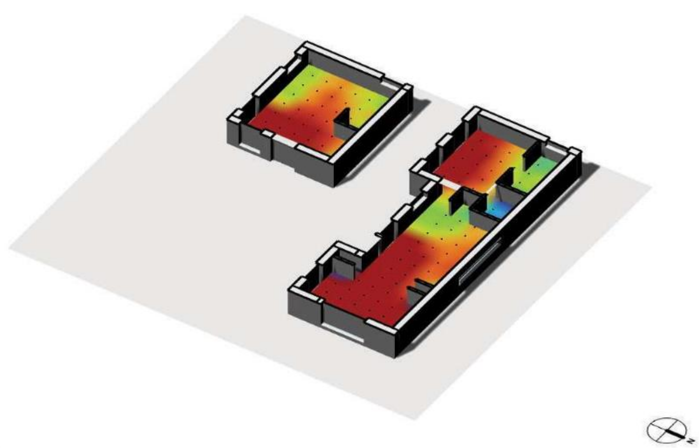

Figure 15. Daylight Distribution Iteration 1

The first iteration, as shown in Figure 14, established a baseline with an sDA of 30.6% and an ASE of 28.7%. These results highlighted poor daylight performance as a result of too many windows in the design. The large number of windows created an uneven daylight distribution, as certain areas were too bright, and others did not have enough sunlight. In addition, the high ASE values indicated that a significant amount of direct sunlight entered the building, leading to high glare and general discomfort. The notes for this iteration signaled that the high ASE values required improved shading or fewer windows. This finding led the students to modify the windows and increase shade to reduce glare and improve sDA. Figure 15 demonstrates how daylight is distributed throughout the interior spaces in the first iteration, highlighting areas of higher and lower exposure.

4.7.7. Daylight Performance Iteration 2

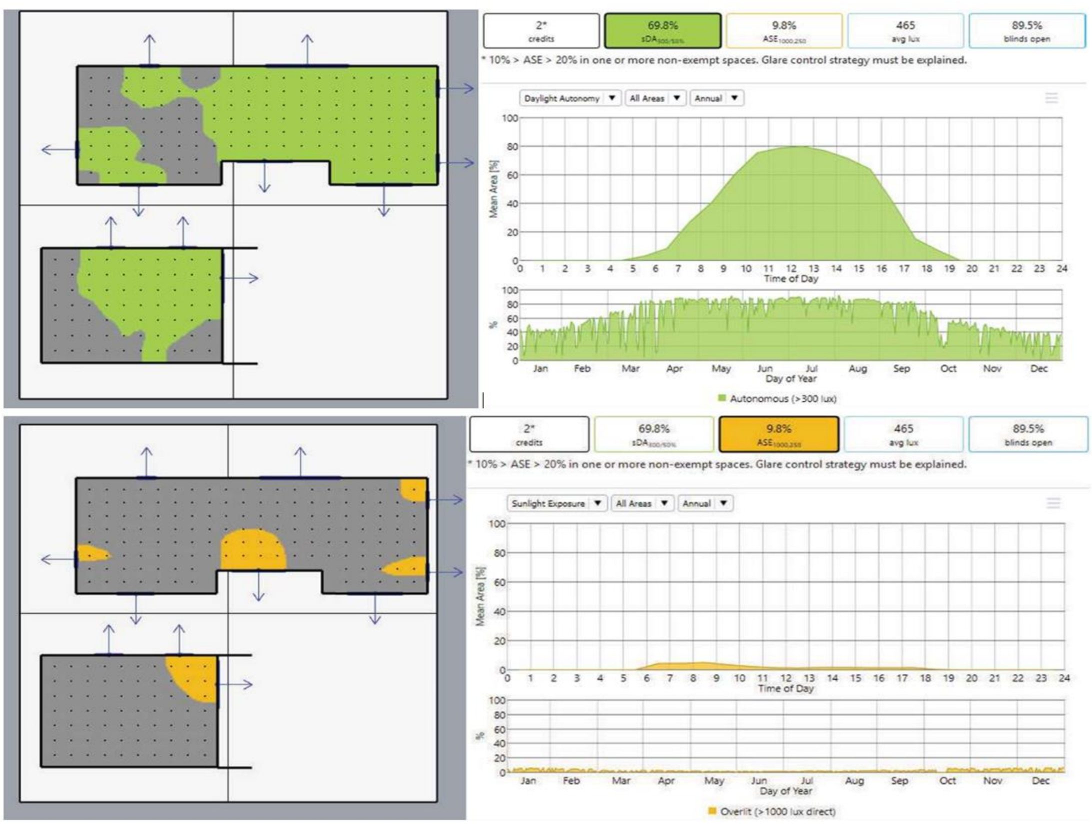

Figure 16. sDA and ASE Iteration 2

During the second iteration, the students adjusted the design to reduce the window area and incorporate proper sun shading correlated with the window direction shade. Following this, a 3 ft overhang on windows was added, and the windows type has been adjusted to double pane with 41% visibility and a U-value of 26. The students were guided by passive strategies learned over the semester, where they designed a sun path diagram, as shown in Figure 9, to help them visualize and gain a greater building performance. The most prominent strategy that the students employed was sun shading and winter thermal gain, which involved carefully positioning shading devices to block excessive sunlight during peak hours while allowing adequate daylight to enter during cooler periods. This approach helped maintain comfortable indoor temperatures and improve daylight distribution throughout the design space.

In addition to shading devices, the students also introduced green walls as thermal barriers on southern-facing walls, which helped to reduce direct heat gain and improve thermal performance. The reasoning behind this strategy was to create a natural buffer that reduced the intensity of sunlight that hit the building envelope, thereby reducing the amount that entered and improving overall comfort. Furthermore, applying the cross-ventilation systems, which involved adjusting the large and small module ventilation designs, improved air circulation and helped distribute daylight more evenly, reducing the need for artificial lighting and increasing daylight autonomy. However, students noted that there were no windows on the south and west sides of the building, resulting in a lack of daylight in some interior spaces. Students have also considered the glare high and aimed to get it below 5%. Some noted strategies were to add horizontal shading and further reduce window visibility. The overall daylight performance outcome significantly increased sDA from 30.6% to 69.8% and reduced ASE from 28.7% to 9.8%, as demonstrated in Figure 16.

4.7.8. Daylight Performance Iteration 3

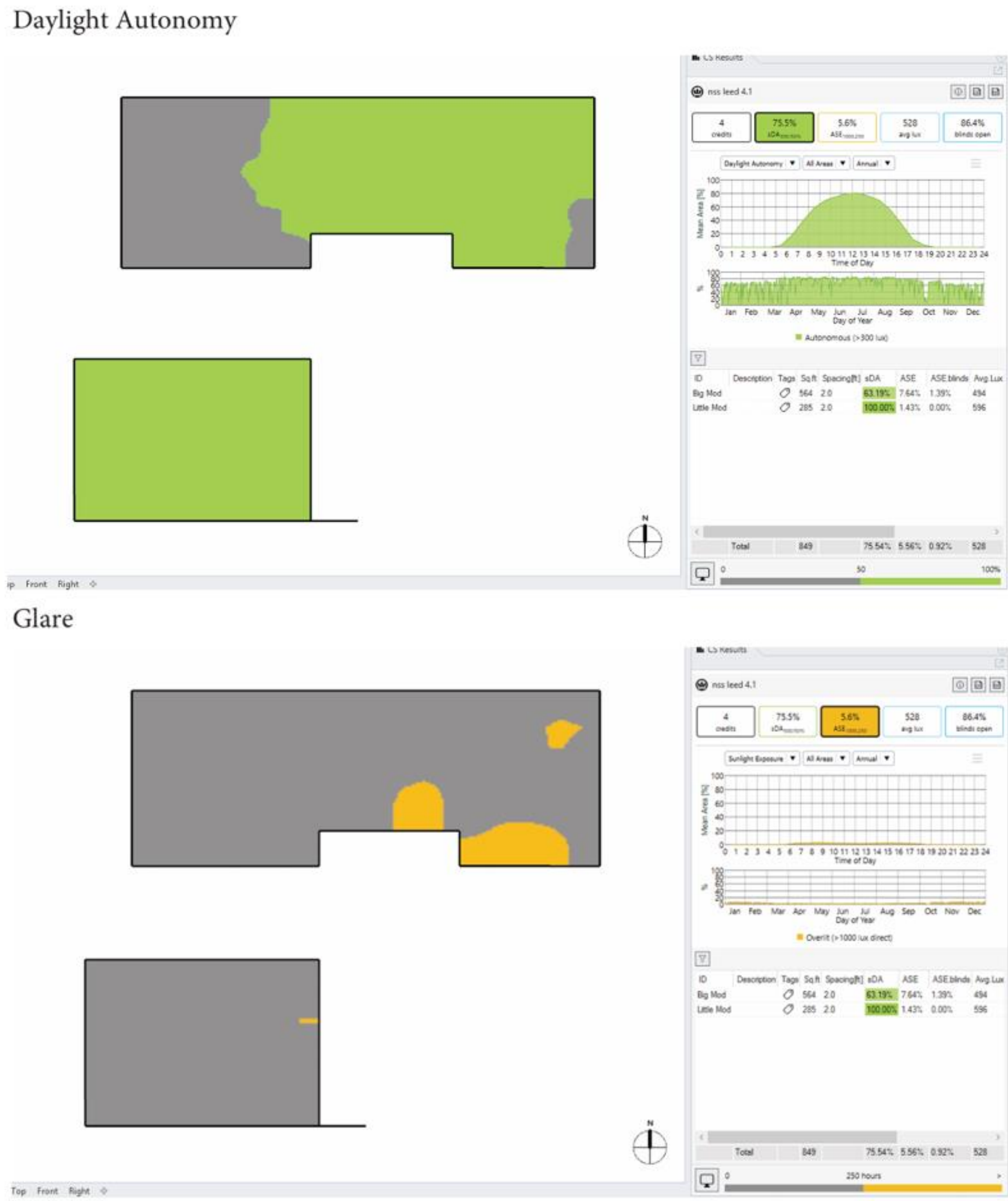

Figure 17. sDA and ASE Iteration 3

The final attempt further refined the balance between daylight autonomy and reduced glare and focused on the 2030 Palette recommendations, which was most evident with the use of the overhangs to create shade. The overhangs were intended to reduce ASE by blocking excessive sunlight while allowing sufficient daylight to reach the desired areas. The simulation results confirmed that this strategy effectively decreased ASE (5.6%) while slightly increasing sDA (75.5%).

4.8. Tracking Building Performance Discussion

The connection between daylight performance and energy use was further evident in relation to the passive strategies. The students reduced both ASE and heating/cooling energy demands by addressing shading devices, adjusting window placement, and improving ventilation techniques. Integrating these design improvements resulted in lower overall source energy use, as demonstrated in Figure 10, by the decrease in total energy use from 77.8 MBtu/yr in Iteration 2 to 52.1 MBtu/yr in Iteration 8. The strategies increased daylight performance, improved thermal comfort, and reduced energy consumption while also maintaining the desired balance between energy efficiency and indoor environmental quality.

The effectiveness of these strategies was tied to students' understanding of the sun's path and their ability to apply this knowledge to improve daylight performance. Integrating cross ventilation, the green wall, and shading angles shows how intelligent design adjustments can lead to desired outcomes. The same is true relative to Iteration 8, where students integrated the final efficiency measures and recalculated the categories to help reach the energy efficiency target. Refining shading devices, adjusting window placement, and applying ventilation techniques provide valuable references for future designs intended to generate enough daylight and keep buildings cool. In short, the simulation demonstrated the usefulness of shading strategies to reduce glare without negatively impacting daylight autonomy. The final attempt indicated the ability to achieve optimal daylight performance, provided that students chose and implemented the appropriate passive design strategies.

Based on performance findings, students showed continuous development in their ability to integrate both active and passive strategies throughout the design iterations. In early design stages, improvements were reflected in design aspects such as insulation and window placement. Later, students' efforts shifted toward refining active strategies, including optimizing heat pump and appliance performance. Overall, the total source energy use dropped by 94 MBtu/yr from the baseline to the final design iteration. This reduction reflects students' advancement in design decisions and the more effective application of active and passive strategies over time, which contributed to significant performance gains. These building performance outcomes indicate the progression of students' abilities to implement energy efficiency concepts in a prefabricated building design.

4.8.1. Daylight Performance Discussion

The iterative process clearly demonstrates the need to understand the sun's path and apply passive strategies to improve daylight performance. During the first iteration, the excessive number of windows resulted in high ASE and poor daylight distribution. This outcome is attributable to the poorly shaded windows, which allowed direct sunlight to enter the design and led to an excessive glare. As a result, students reevaluated window placement and incorporated shading techniques to control daylight distribution, helping to maintain indoor temperature and reduce heating demand.

The second iteration marked a significant improvement in daylight performance. The sun-shading angles and winter thermal gain strategy reduced solar heat gain during peak hours, allowing natural light to enter the building during cooler periods while blocking excessive sunlight. The ASE values were successfully reduced due to the incorporation of shading devices and strategic window placement. Moreover, the adjustments made to the building’s ventilation system contributed to a slight increase in SDA, indicating that the passive strategies employed were effectively enhancing daylight performance without compromising thermal comfort. If nothing else, this approach underscores the need to manipulate shading angles to achieve a balance between daylight access and thermal comfort. Finally, this iteration shows how upgrading HVAC systems and greater energy efficiency can reduce heating and cooling energy demands.

Additionally, the daylight performance improvements contributed to a reduction in overall energy use. Higher daylight autonomy reduced the dependence on artificial lighting, which lowered source energy use. The relationship between daylight performance and source energy use became apparent when comparing the findings to the Iteration 4 bar graph, where window type and sun path were analyzed. Improved daylight distribution reduced the need for artificial lighting during daylight hours, directly impacting energy loads. Reduced glare contributed to lower heating and cooling demands since excessive glare can increase internal heat gain, forcing HVAC systems to work harder to cool the building. Therefore, reducing glare also indirectly decreased energy loads associated with cooling.

Introducing green walls also improved thermal performance by reducing heat gain on southern-facing walls. This strategy improved thermal comfort and helped balance the distribution of daylight. Applying the cross-ventilation systems benefitted air circulation and created a more comfortable and functional environment. By the final attempt, the students had refined their approach, using the 2030 Palette recommendations to apply the appropriate shading devices. The overhangs reduced ASE and improved daylight autonomy. Improved slab insulation leads to greater thermal efficiency in the building envelope, consistent indoor temperatures, and reduced demand for heating. The slight increase in sDA, combined with the reduced ASE, demonstrated the effectiveness of the utilized strategies to optimize daylight performance without sacrificing thermal comfort.

4.9. Hands-On Building Experience Results

Students participated directly in constructing a section of the building as part of the design-build experience. This section presents figures depicting the construction process and the materials used for the constructed portion of the building.

Figure 18. Floor Constructing Process Part 1

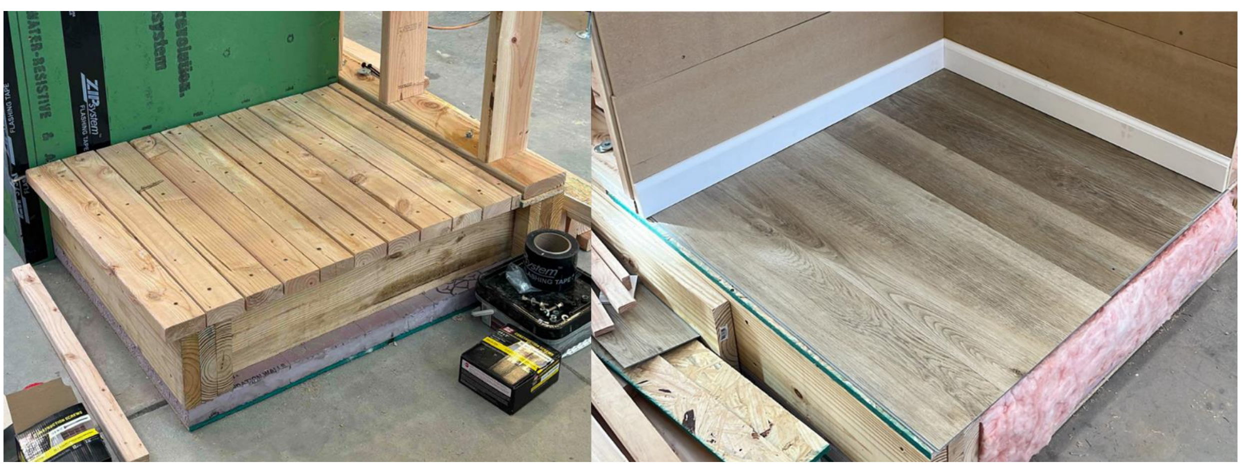

Figure 19. Floor Constructing Process Part 2

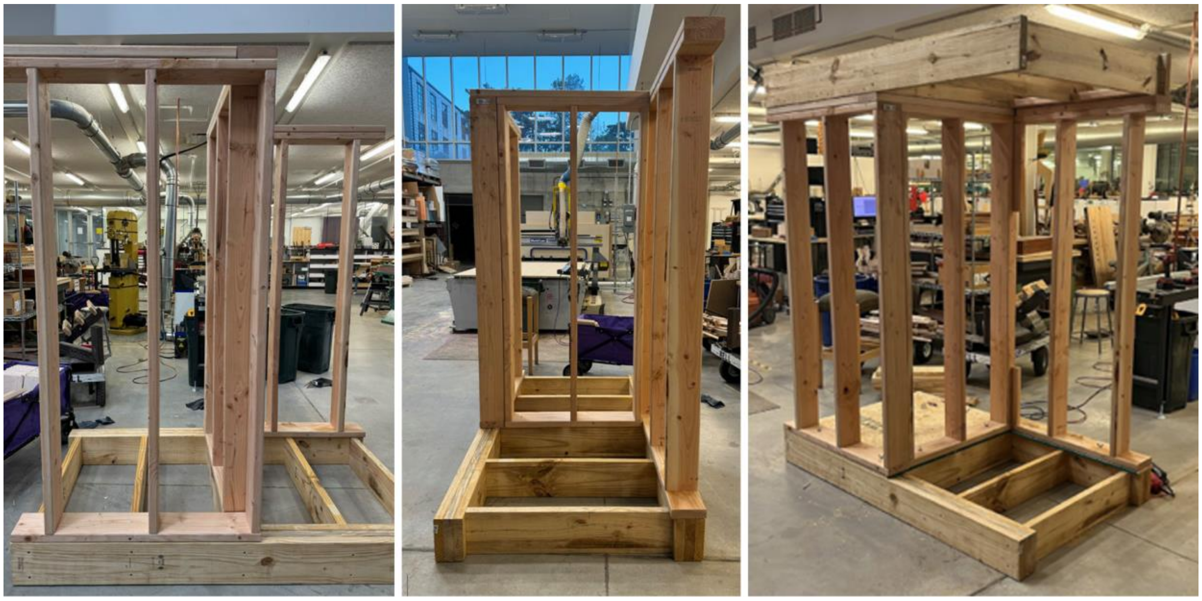

Figure 20. Advanced Framing

Figure 21. 5-1/2" Fiberglass Insulation

Figure 22. Installing Wall Rigid Insulation and ZIP Sheathing

Figure 23. Installing Roof Rigid Insulation and ZIP Sheathing

Figure 24. Implementation of Wood Cladding

Figure 25. Implementation of Fiber Cement Cladding

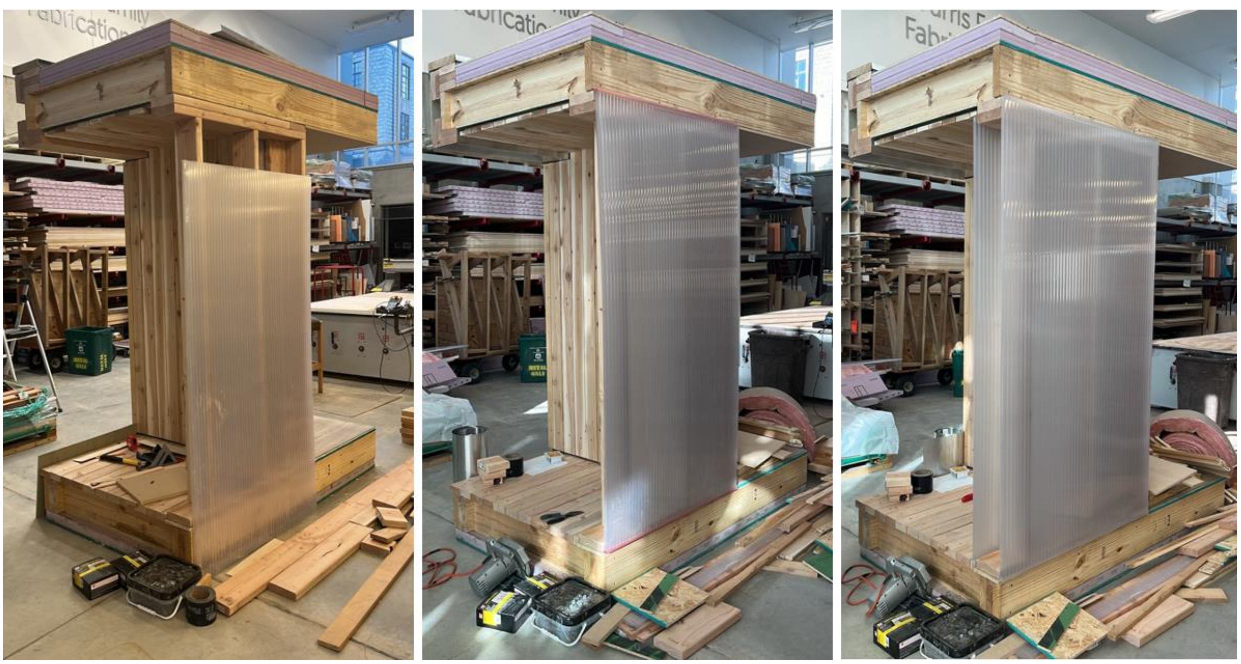

Figure 26. Polycarbonate on Stud Wall

Figure 27. Completed Building Section Part 1

Figure 28. Completed Building Section Part 2

4.10. Chapter Conclusion

This chapter addressed the study result and discussion and revealed how students' understanding of energy efficiency principles developed over an interdisciplinary real-world project. The outcomes demonstrated not only the effective application of energy efficiency concepts in a prefabricated design to achieve net-zero energy, but also how interdisciplinary collaboration shaped students' perspectives and design decisions. In addition, a brief section describes the transition from theoretical to practical work and shows how students engaged with building materials during part of the construction process. Overall, the chapter offers a broad view of how students developed their designs, deepened their perspectives, and advanced their learning over time, setting the stage for the final discussion of the study's contributions, limitations, and directions for future research.

CHAPTER FIVE: CONCLUSION

5.0. Chapter Introduction

The research has examined student understanding of the principles of energy efficiency in the design and construction of an NZEB through a real-world, interdisciplinary project. This chapter summarizes the primary insights and highlights the broader implications of this for fields that include architectural education, sustainability, and design pedagogy. In addition, it addresses methodological limitations and opportunities for future research before concluding.

5.1. Discussion Overview

The study revealed that student understanding of NZEB principles significantly improved as the studio project went forward, allowing them to make the needed adjustments to demonstrate how to conserve energy, ensure comfortability, and reflect sustainable design thinking in real-world applications. As the pre- and post-surveys indicated, students became more confident and familiar with energy efficiency strategies from the start to the end of the project and developed their appreciation for the importance of sustainable design. Interviews and observations substantiated the value of experiential learning, indicating that students not only developed their conceptual understanding of NZEB but also improved their problem-solving abilities, as the changes they made throughout the project confirm. Finally, the feedback that students received from the modeling tools, along with their revised designs and student collaboration, was critical to the positive performance outcomes.

An equally compelling finding was how the students applied passive and active design strategies to understand and overcome the challenge that NZEBs present. Adjusting window placement for daylighting, using exterior insulation to control temperature, and integrating solar panels to generate renewable energy were some of the ways that students successfully managed the challenges that they confronted. In short, the project demonstrates how student learning translated into measurable NZEB performance. By the final iteration, students had reduced the building's total energy and successfully balanced glare with natural lighting. Evidently, students understood how to apply their growing awareness of NZEB principles to create a building design that one might realistically encounter outside of a classroom setting.

5.2. Methodological Limitations

Although the methodology was appropriate and helped guide the students to success, it did exhibit several limitations worth addressing.

First, the study relied on a single academic cohort—students enrolled in a one-semester architecture studio participating in the Gateway Decathlon Project— limiting the ability to generalize any findings. The discussed results reflect the experiences and progress of these students and thus may not fully account for how other students would experience or progress on this project.

Second, only 23 of 60 students completed the pre- and post-surveys, potentially introducing self-selection bias into the study. In other words, students who may have been more engaged or confident in their understanding of energy efficiency principles and NZEB design may have been more likely to respond, whereas those with less confidence may have opted to leave the study. Similarly, the interviews only included 10 students, limiting the range of potential perspectives and possibly discounting useful views and ideas.

Third, observation data focused on the performance team, possibly overlooking the contributions and challenges that the systems, envelope, or design teams encountered. Such emphasis may influence interpretation toward technical perspectives and prevent a holistic understanding of how the entire student performed.

Fourth, the study tracked building performance using BEopt and Climate Studio and the construction of a portion of the building only. Modeling tools may generate useful insight into energy use and daylight performance but do not account alone for real-world issues that may arise. In addition, the design was not fully constructed since the competition was canceled, limiting students' ability to physically build their project. As a result, one cannot collect a complete assessment of how student learning would materialize in a real-world context.

5.3. Future Research

One area of potential future research concerns tracking student understanding and performance over more than a single semester and perhaps into professional practice. By taking this longitudinal approach, scholars could determine how student learning influenced professional practice, as well as its strengths and weaknesses, leading educators to refine their pedagogy. Additionally, scholars may explore how interdisciplinary collaboration, such as the type witnessed in this study, develops and shapes innovation and how students think about sustainability. Given the importance of sustainability in architecture and various other related fields, findings that reflect the relationship between interdisciplinary collaboration, on the one hand, and innovation and sustainability, on the other, could offer valuable guidance for educators, professionals, and other stakeholders.

A third avenue of potential future research reflects post-occupancy evaluations to assess how student-designed NZEBs perform in practice. To this end, scholars may compare studies from different academic institutions in order to refine teaching practices and ensure that students leave their studies with the aptitude needed to design NZEBs successfully. Finally, scholars might consider examining how the use of simulation tools and rating systems such as LEED could improve student confidence and prepare them to thrive in the building industry.

5.4. Conclusion

This research demonstrates that real-world, interdisciplinary, project-based learning can greatly improve students' understanding of energy efficiency and sustainable design. Over the semester, students developed their understanding of NZEB principles through iterative design, performance tools, and interdisciplinary collaboration, showcasing their finished project to much applause. Broadly speaking, this research illustrates the need for sustainability to be part of architectural education in both theory and practice, as its integration would prepare future designers and engineers to shape an industry that has degraded the environment and contributed to climate change. Given the existential threat that these issues pose to humanity, it is imperative that educators focus on sustainability, empowering students to be prepared to lead the transition to a more sustainable built environment.

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Appendices

Appendix A – Survey Results

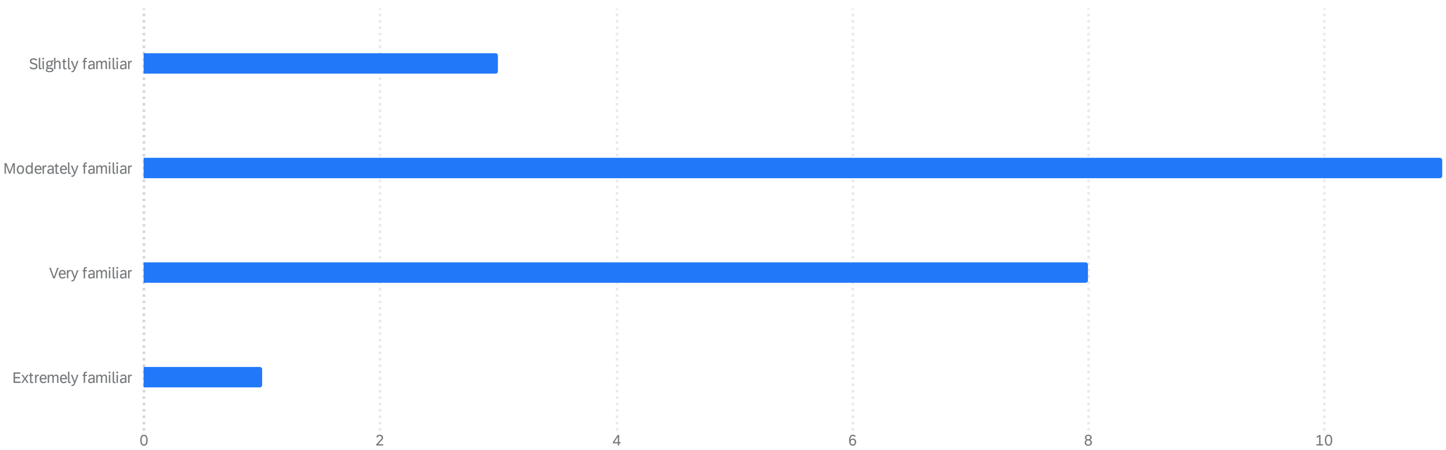
Pre-Survey Results / Page 1

Responses: 23

1- On a scale from 0 to 10, where 0 means no knowledge and 10 means highly knowledgeable, how would you rate your understanding of net-zero energy?
23

1- On a scale from 0 to 10, where 0 means no knowledge and 10 means highly...	Average	Minimum	Maximum	Count
Click to write Choice 1	5.74	3.00	9.00	23

How familiar are you with the concept of energy efficiency? 23



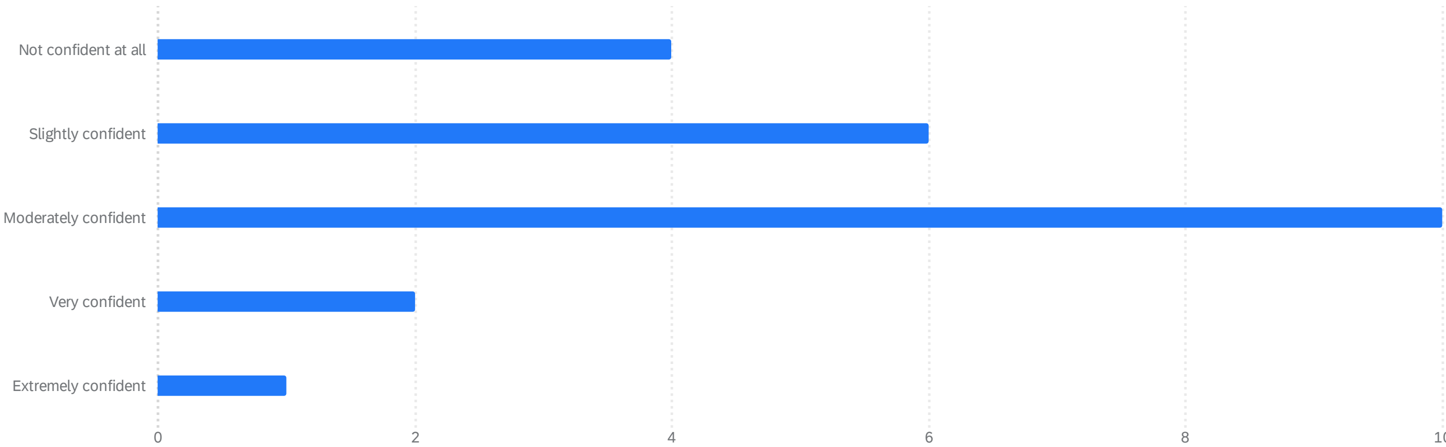
How familiar are you with the concept of energy efficiency? 23

Q2 - How familiar are you with the concept of energy efficiency?	Percentage	Count
Slightly familiar	13%	3
Moderately familiar	48%	11
Very familiar	35%	8
Extremely familiar	4%	1

How familiar are you with the concept of energy efficiency? 23

How familiar are you with the concept of energy efficiency?	Average	Minimum	Maximum	Count
Slightly familiar	2.00	2.00	2.00	3
Moderately familiar	3.00	3.00	3.00	11
Very familiar	4.00	4.00	4.00	8
Extremely familiar	5.00	5.00	5.00	1

How confident are you in your ability to design a net-zero energy building? 23



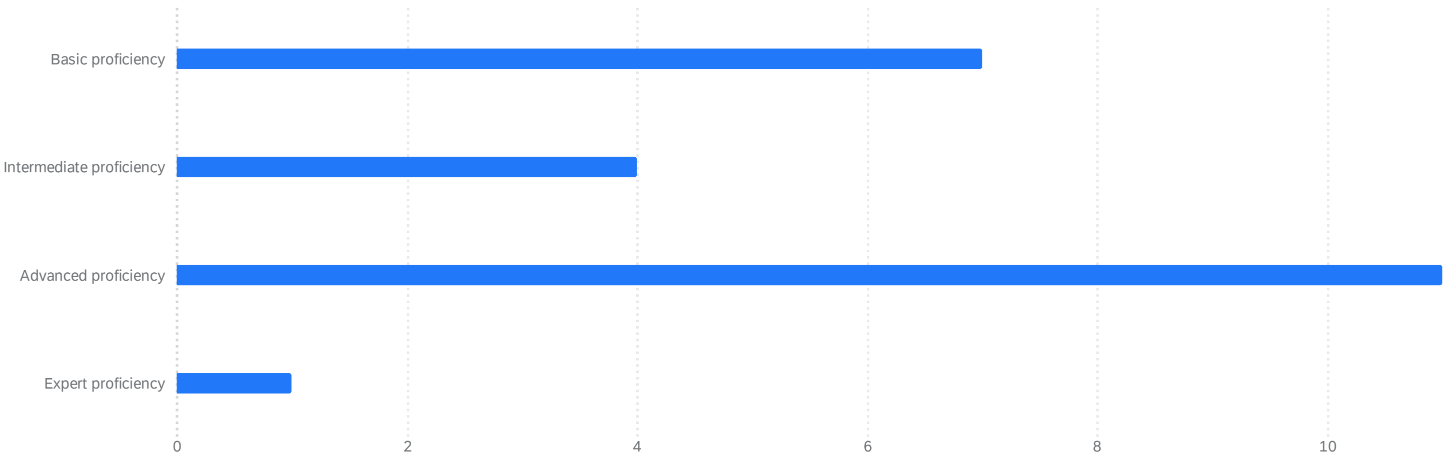
How confident are you in your ability to design a net-zero energy building? 23

Q3 - How confident are you in your ability to design a net-zero energy building?	Percentage	Count
Not confident at all	17%	4
Slightly confident	26%	6
Moderately confident	43%	10
Very confident	9%	2
Extremely confident	4%	1

How confident are you in your ability to design a net-zero energy building? 23

How confident are you in your ability to design a net-zero energy building?	Average	Minimum	Maximum	Count
Not confident at all	1.00	1.00	1.00	4
Slightly confident	2.00	2.00	2.00	6
Moderately confident	3.00	3.00	3.00	10
Very confident	4.00	4.00	4.00	2
Extremely confident	5.00	5.00	5.00	1

What level of proficiency do you think you will achieve with net-zero design by the end of the semester? 23



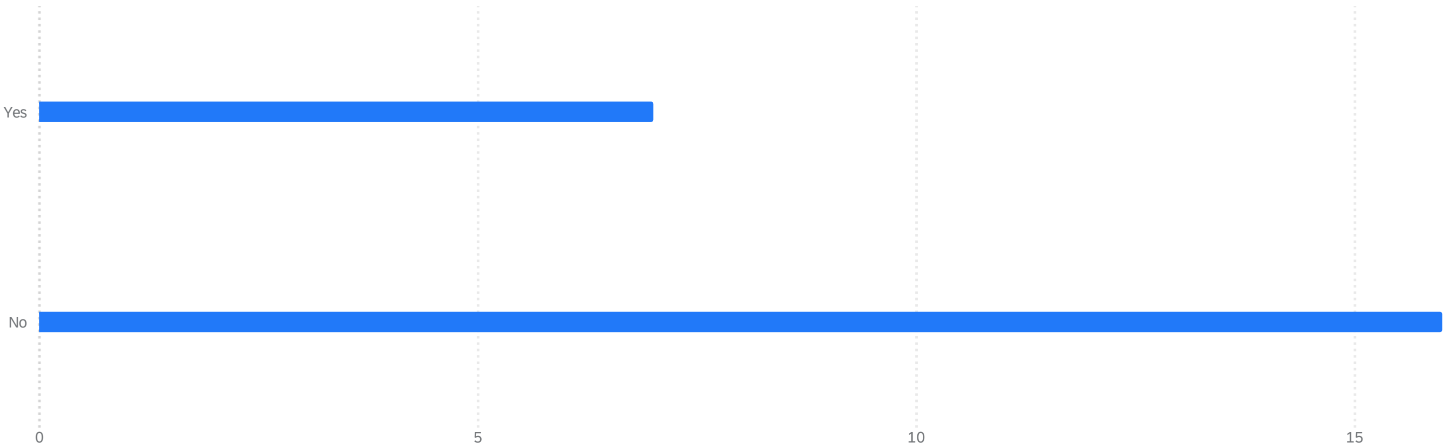
What level of proficiency do you think you will achieve with net-zero design by the end of the semester? 23

Q4 - What level of proficiency do you think you will achieve with net-zero design by the end of the semester?	Percentage	Count
Basic proficiency	30%	7
Intermediate proficiency	17%	4
Advanced proficiency	48%	11
Expert proficiency	4%	1

What level of proficiency do you think you will achieve with net-zero design by the end of the semester? 23

What level of proficiency do you think you will achieve with net-zero desig...	Average	Minimum	Maximum	Count
Basic proficiency	2.00	2.00	2.00	7
Intermediate proficiency	3.00	3.00	3.00	4
Advanced proficiency	4.00	4.00	4.00	11
Expert proficiency	5.00	5.00	5.00	1

Have you worked on or studied any projects related to energy-efficient or sustainable design before? If yes, please name them. 23



Have you worked on or studied any projects related to energy-efficient or sustainable design before? If yes, please name them. 23

Q5 - Have you worked on or studied any projects related to energy-efficient or sustainable design before? If yes, please name them. - Selected Choice	Percentage	Count
Yes	30%	7
No	70%	16

Have you worked on or studied any projects related to energy-efficient or sustainable design before? If yes, please name them. 23

Have you worked on or studied any projects related to energy-efficient or s...	Average	Minimum	Maximum	Count
Yes	1.00	1.00	1.00	7
No	2.00	2.00	2.00	16

Have you worked on or studied any projects related to energy-efficient or sustainable design before? If yes, please name them.: Yes 23

Yes

Decathlon Spring Studio

Decathlon spring

Yes

Bullit Center

The Edge Building (EU)

ESA with Gibson

What do you think will be the biggest challenges in designing a net-zero energy building? 23

What do you think will be the biggest challenges in designing a net-zero en...

Making it affordable

Finding a balance of energy ideas to get the best result

Keeping cost low while designing it to be net-zero

The cost

Explaining to people who don't understand net zero that things do actually have to be net zero

How to make the building affordable

Learning different types of efficient systems. Also learning what systems may be scams.

Energy Production

Acquiring the amount of energy and water from your sustainable methods to meet the yearly demand.

I feel like finding systems that can actually achieve net-zero and doing all the right calculations to make it work

Getting enough power to have a functioning building

Combatting solar heat gains

Making sure everything actually works

not missing anything that can contribute to the energy use of the building

Finding cutting edge, sustainable solutions

How to make it cost effective. Everything we have been taught thus far is it's all very expensive to implement and has a long payback period

HVAC systems don't have a lot of research on how to make them more energy efficient.

Achieving net zero through the systems we use.

Price

Understanding and finding information on the systems and materials required

Finding Cost Effective solutions

What do you think will be the biggest challenges in designing a net-zero en...

Producing enough energy to meet the consumption

What initial design strategies do you plan to explore to achieve net-zero energy performance? 23

What initial design strategies do you plan to explore to achieve net-zero e...

Renewable energy and efficient systems

Good wall assembly and rain water collection

Natural ventilation, passive solar gain, underground mechanical systems

Wind and solar energy. Materials and system selection

Overhangs, ventilation, daylighting and thermal mass

Research and self learning is the only way to learn these systems. After learning the systems, trying to figure out how they work together is the next challenge. It is tough to initially design with little to no knowledge.

Study the site to implement passive design concepts.

Integrating solar power and rainwater collection to reduce the amount of energy and water from the utility, reducing emissions and cost.

using efficient engineering systems

Harvesting techniques (wind, solar etc)

Shading windows and solar panels

Working on natural ventilation through the design as well as thinking logically about it natural light and water collection.

solar power generation, rainwater collection

Electrified glass, solar energy

Solar energy, efficient equipment and fixtures, water collection

Major use of solar panels, rainwater collection

Research into similar homes

What initial design strategies do you plan to explore to achieve net-zero e...

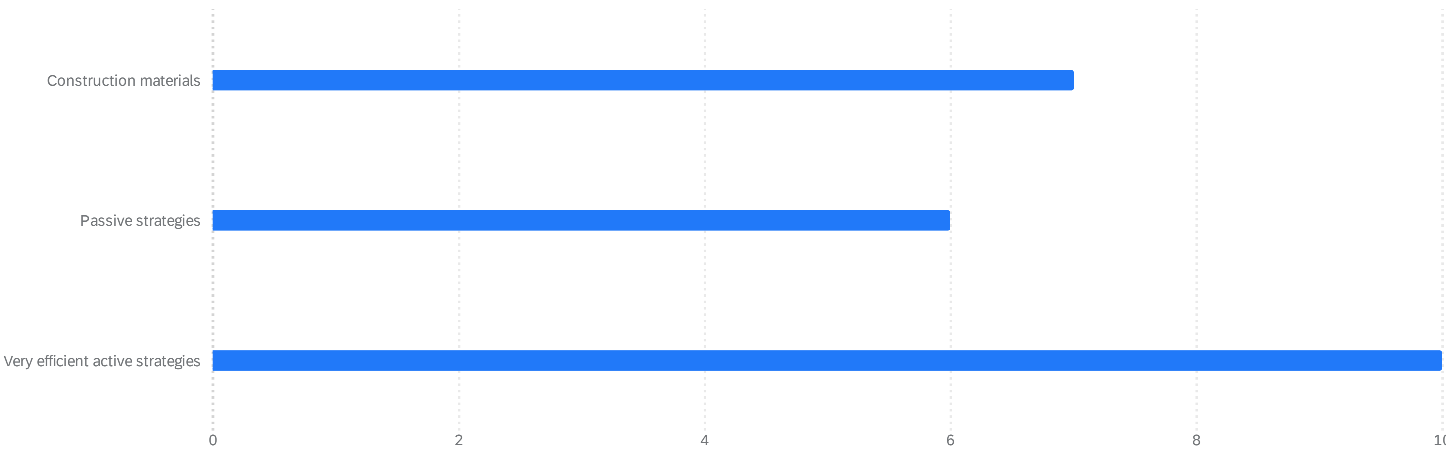
simple things like windows, shading, water collection, choice of utility

Passive design, MEP systems, solar panel usage, and water reuse

Solar heating and cross ventilation for cooling

Solar pannels

Do you think having construction materials, passive or very efficient active strategies in the building design is most important? 23



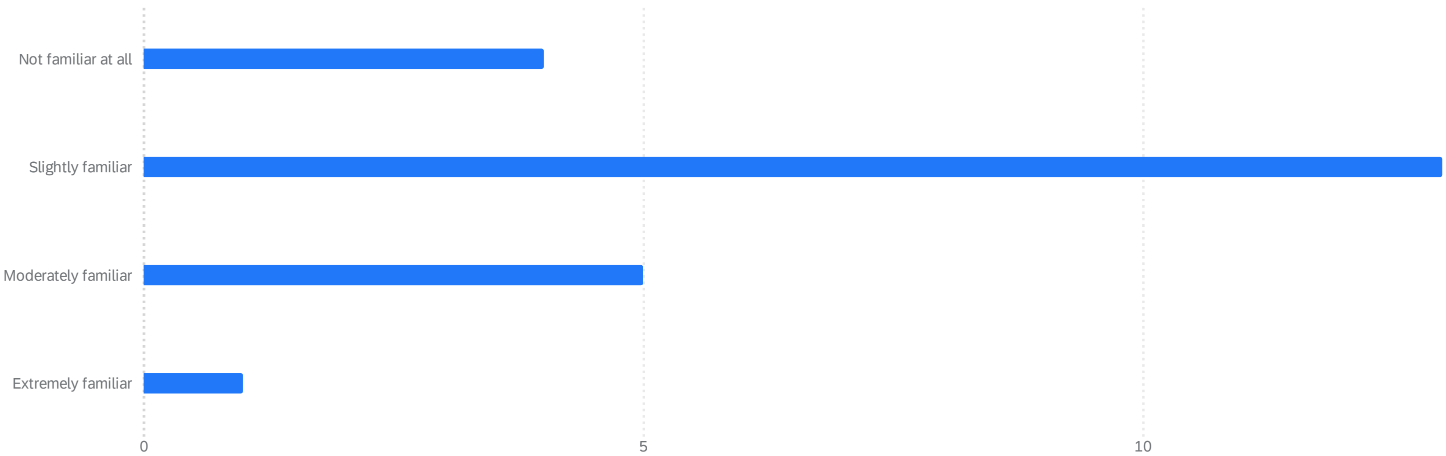
Do you think having construction materials, passive or very efficient active strategies in the building design is most important? 23

Q9 - Do you think having construction materials, passive or very efficient active strategies in the building design is most important?	Percentage	Count
Construction materials	30%	7
Passive strategies	26%	6
Very efficient active strategies	43%	10

Do you think having construction materials, passive or very efficient active strategies in the building design is most important? 23

Do you think having construction materials, passive or very efficient activ...	Average	Minimum	Maximum	Count
Construction materials	1.00	1.00	1.00	7
Passive strategies	2.00	2.00	2.00	6
Very efficient active strategies	3.00	3.00	3.00	10

How familiar are you with energy modeling tools or software that can help you calculate energy efficiency? 23



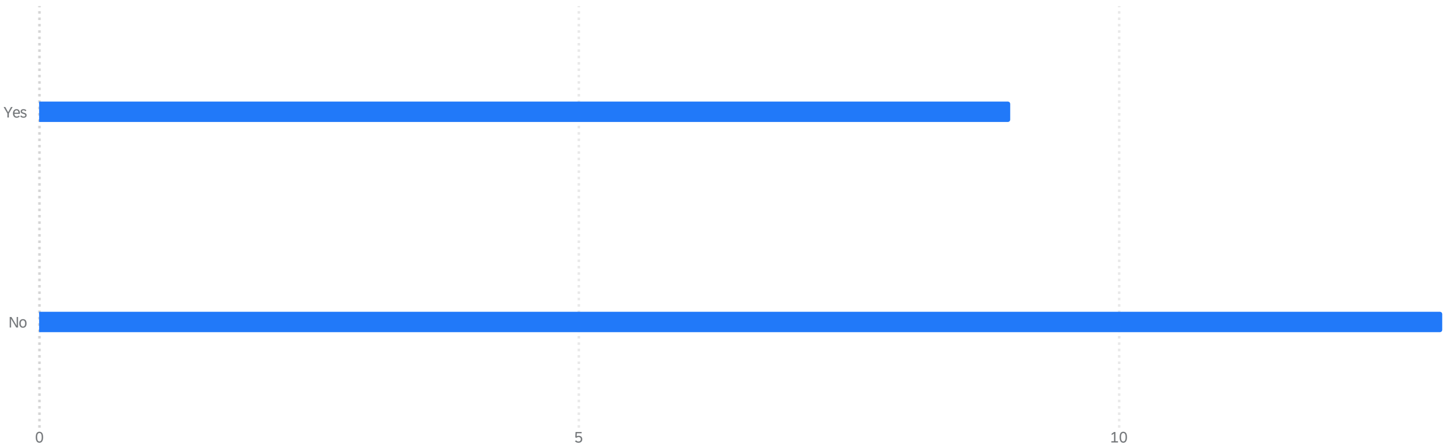
How familiar are you with energy modeling tools or software that can help you calculate energy efficiency? 23

Q11 - How familiar are you with energy modeling tools or software that can help you calculate energy efficiency?	Percentage	Count
Not familiar at all	17%	4
Slightly familiar	57%	13
Moderately familiar	22%	5
Extremely familiar	4%	1

How familiar are you with energy modeling tools or software that can help you calculate energy efficiency? 23

How familiar are you with energy modeling tools or software that can help y...	Average	Minimum	Maximum	Count
Not familiar at all	1.00	1.00	1.00	4
Slightly familiar	2.00	2.00	2.00	13
Moderately familiar	3.00	3.00	3.00	5
Extremely familiar	5.00	5.00	5.00	1

Do you know any energy efficiency rating systems? If yes, please name them. 22



Do you know any energy efficiency rating systems? If yes, please name them. 22

Q12 - Do you know any energy efficiency rating systems? If yes, please name them. - Selected Choice	Percentage	Count
Yes	41%	9
No	59%	13

Do you know any energy efficiency rating systems? If yes, please name them. 22

Do you know any energy efficiency rating systems? If yes, please name them.	Average	Minimum	Maximum	Count
Yes	1.00	1.00	1.00	9
No	2.00	2.00	2.00	13

Do you know any energy efficiency rating systems? If yes, please name them.: Yes 23

Yes

Hers, eui

Yes

LEED

LEED

Leed

Climate studio

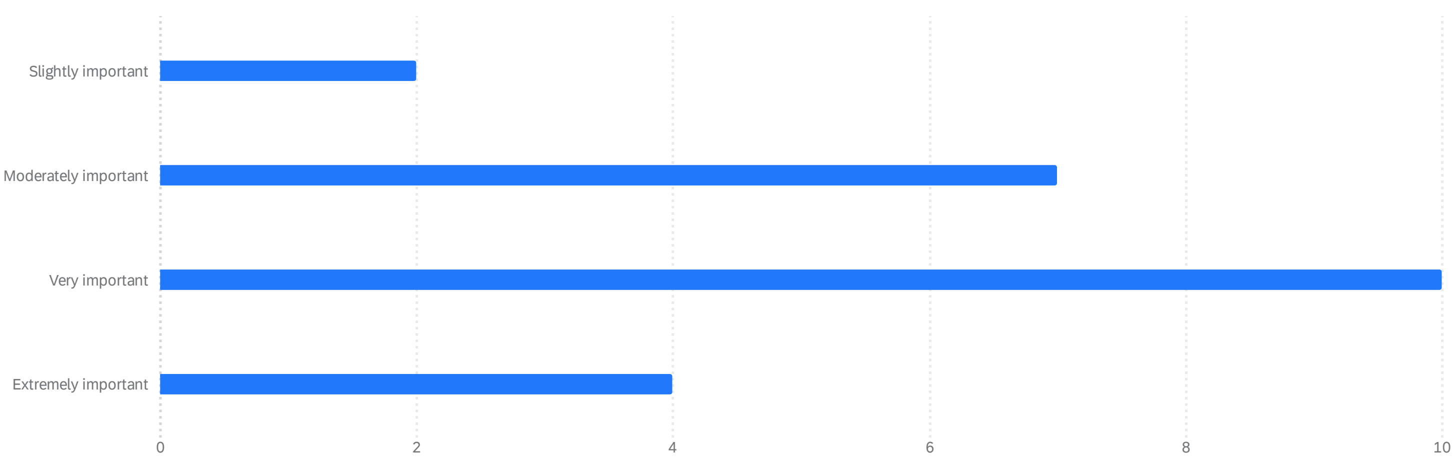
Trace700

LEED, Enerstar

HERS, LEED

ENERGY STAR

How important do you think net-zero design will be in your future projects? 23



How important do you think net-zero design will be in your future projects? 23

Q13 - How important do you think net-zero design will be in your future projects?	Percentage	Count
Slightly important	9%	2
Moderately important	30%	7
Very important	43%	10
Extremely important	17%	4

How important do you think net-zero design will be in your future projects? 23

How important do you think net-zero design will be in your future projects?	Average	Minimum	Maximum	Count
Slightly important	2.00	2.00	2.00	2
Moderately important	3.00	3.00	3.00	7
Very important	4.00	4.00	4.00	10
Extremely important	5.00	5.00	5.00	4

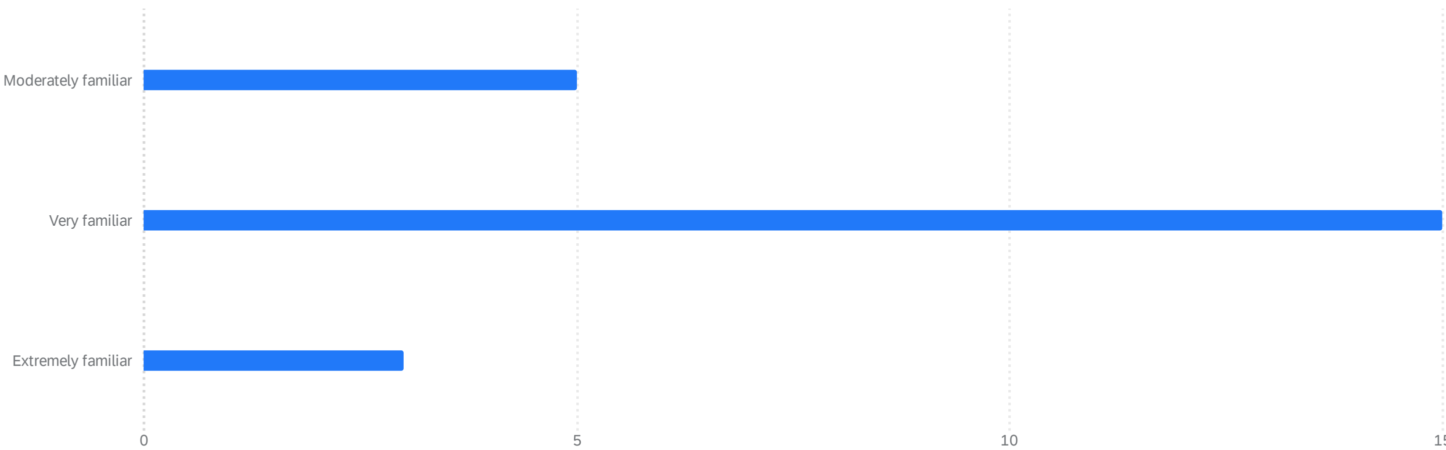
Post-Survey Results / Page 1

Responses: 23

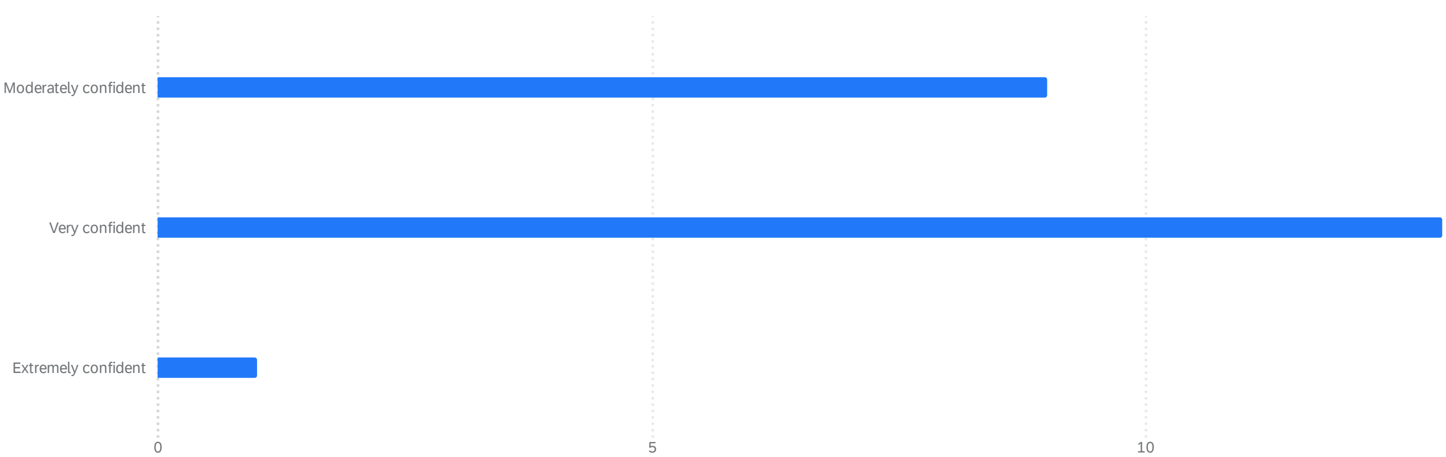
1- On a scale from 0 to 10, where 0 means no knowledge and 10 means highly knowledgeable, how would you rate your understanding of net-zero energy? 23

1- On a scale from 0 to 10, where 0 means no knowledge and 10 means highly...	Average	Minimum	Maximum	Count
Click to write Choice 1	7.70	6.00	10.00	23

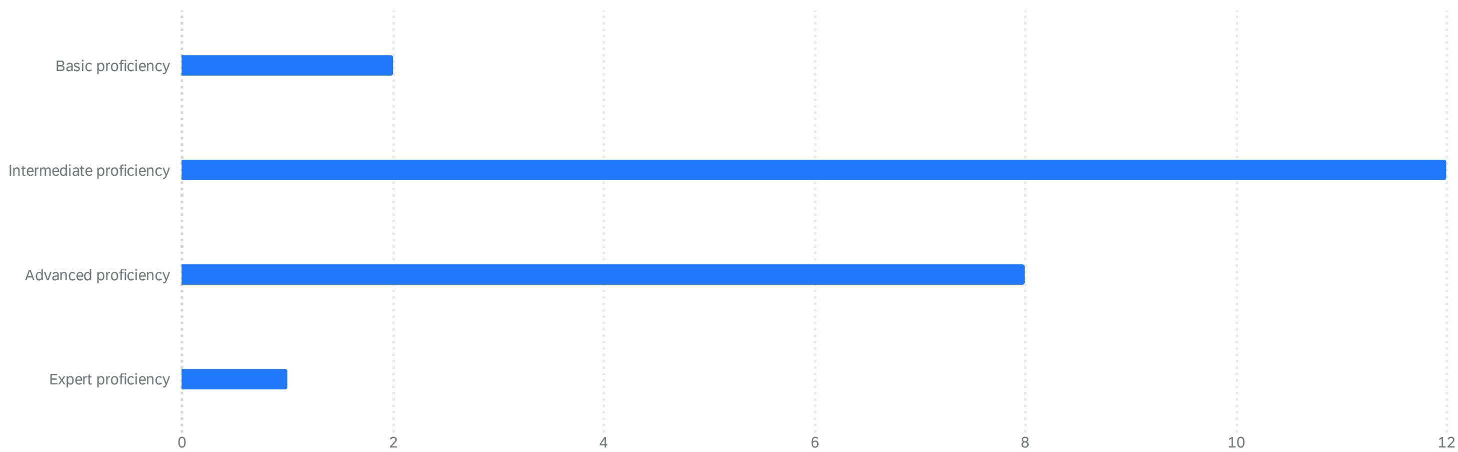
2- How familiar are you with the concept of energy efficiency? 23



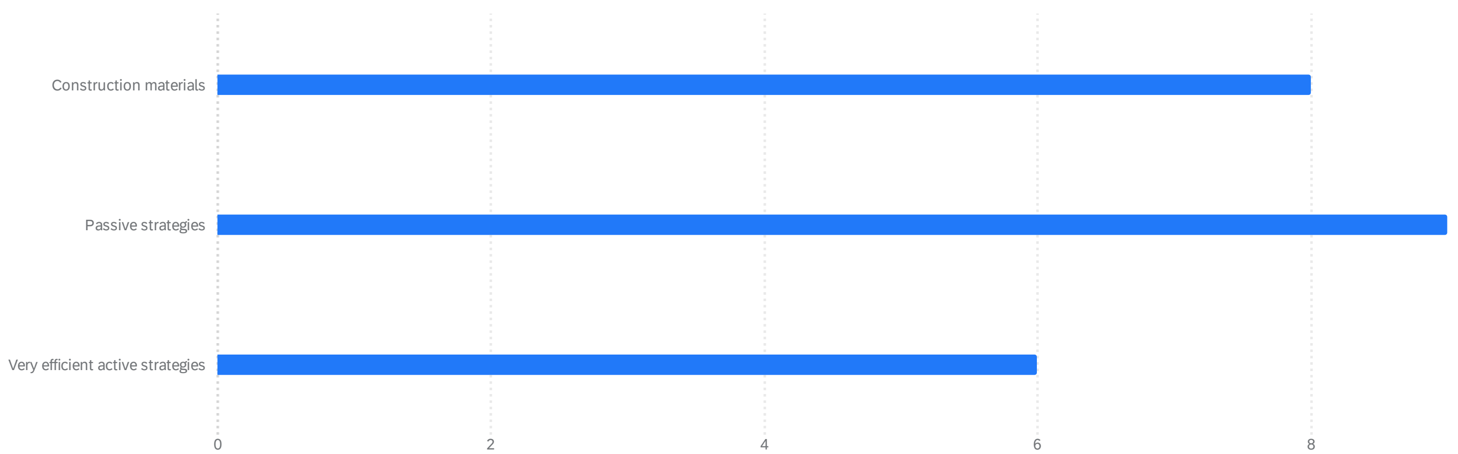
3- How confident are you now in your ability to design a net-zero energy building? 23



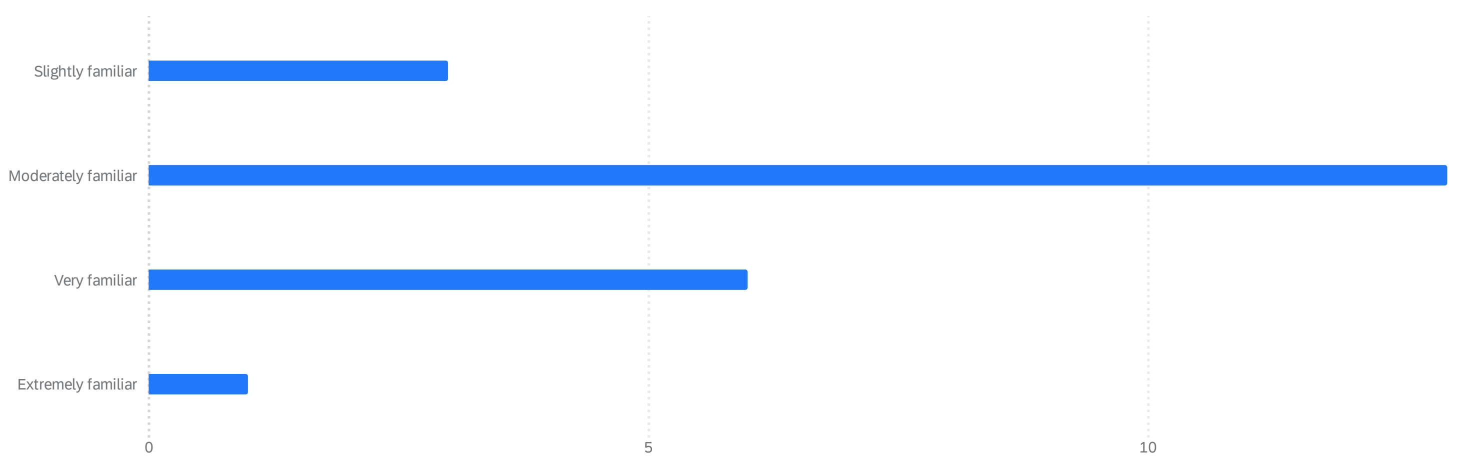
4- What level of proficiency do you think you have achieved with net-zero design? 23



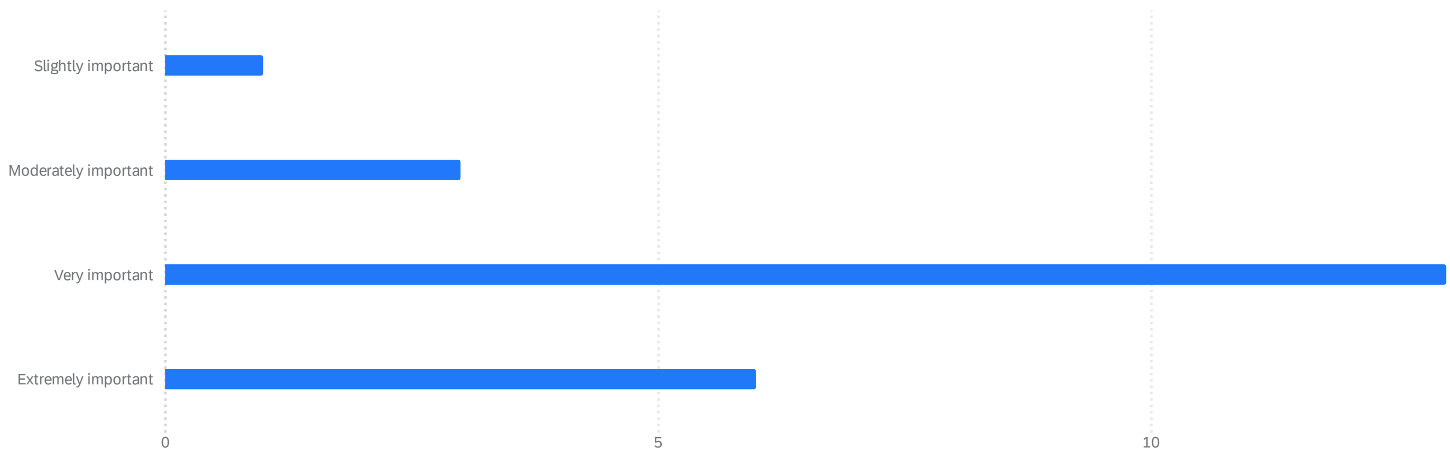
5- Do you think having construction materials, passive or very efficient active strategies in the building design is most important? 23



6- How familiar are you now with energy modeling tools or software that can help you calculate energy efficiency? 23



7- How important do you think net-zero design will be in your future projects? 23



Appendix B – Transcribed Interviews

<u>Interview Outline</u>

Introduction:

Explain the purpose of the interview

Understanding and Learning Experience:

1- At the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies from 1 to 10? Where did you learn about them?
2- What were your initial thoughts about achieving net-zero energy in the project?
3- How did your understanding change as the project progressed?
4- Was there a specific moment or lesson that significantly shifted your perspective?
5- Which concepts did you find most challenging to understand?
6- How did working on a real-world project influence your learning experience compared to traditional academic exercises?

Design Decisions:

7- "Envelope" Can you describe one major design decision you made related to energy efficiency? And what factors influenced this decision?
8- Did the site orientation play a role in your energy efficiency strategy? If yes, how?
9- What passive strategies have you used? And which one do you think made a big difference with energy efficiency?
10- How did your design change based on feedback from professors or peers?

Software and Tools:

11- "For performance team" Did any unexpected challenges occur during the modeling process with BEopt or Climate Studio? How did you handle them?
12- Do you feel these tools provided a clear understanding for your design decisions? Why or why not?

Collaboration:

13- Which team are you part of? And which other teams do you closely work with?
14- How did collaboration with other teams impact your work on the project?
15- How did the workflow between the team manifest?
16- How did you communicate with the other teams?
17- Do you think working as part of a team influenced your understanding of energy efficiency? If so, how?

Takeaways:

18- What do you think was the most valuable lesson you learned from this project?

Participant 1

Speaker 1 • 0:00 - 0:23 • 94%
so just to explain the purpose of the interview, I'm doing this for my thesis

So first question is,

Q1: at the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies? Out of 10?

Speaker 2 • 0:25 - 0:26 • 98% Probably like four.

Speaker 1 • 0:26 - 0:29 • 95%
Where did you learn about those? From

Speaker 2 • 0:29 - 0:39 • 91%
Where? I think one of Mc Glen's classes.

Speaker 1 • 0:41 - 0:41 • 69% ESA called

Speaker 2 • 0:41 - 0:45 • 82%
ESA?

Speaker 1 • 0:46 - 0:50 • 97%
Q2. What were your initial thoughts about achieving net zero energy in the project?

Speaker 2 • 0:54 - 1:07 • 94%
It, it was harder than I thought. A lot more in depth than I would've thought. But yeah, I think we got to a good place that I did learn a lot.

Speaker 1 • 1:08 - 1:11 • 98%
Q3. How did your understanding change as the project progressed?

Speaker 2 • 1:13 - 1:34 • 97%
Like I said, it was more, more in depth. It covered a lot more bases than I knew and there's a lot more like, like the scientific bases for it. I didn't know much about that. I just knew the basics for like the architecture strategies,

Speaker 1 • 1:35 - 1:41 • 96%
Q4. Was there a specific moment or lesson that significantly shifted your perspective?

Speaker 2 • 1:43 - 1:57 • 96%
No. Maybe when we started like doing the calculations on climate consultant, that puts like all the graphs and charts together and it gives you a bigger idea of how energy performance is.

Speaker 1 • 1:57 - 2:02 • 94%
Q5. Which concepts do you find most challenging to understand?

Speaker 2 • 2:04 - 2:26 • 97%
Probably thermal installation and how to block unwanted heat or cool air while also providing opportunity to let heat ankle air in and out when you do want it.

Speaker 1 • 2:26 - 2:37 • 93%
Q6. How did working on a real world project influence your learning experience compared to traditional academy exercises?

Speaker 2 • 2:38 - 2:48 • 96%
Well, you had to put all the strategies in like one design, so incorporating all of them rather than just learning about them in separate ones or examples. Teachers that given us was helpful

Speaker 1 • 2:49 - 2:55 • 92%
So you think it's like there's a difference between working on a real project or like just normal one?

Speaker 2 • 2:55 - 2:55 • 99% For
Yeah, sure.

Speaker 1 • 2:56 - 3:03 • 98%
Q7. Can you describe one major design decision you made related to energy efficiency?

Speaker 2 • 3:07 - 3:31 • 96%
Hmm. Yeah, probably the layout of our modules that Maddie and I had worked on, choosing to do a long linear plan instead of a normal square rectangle one. It was just like a long rectangle to consider cross-ventilation

Speaker 1 • 3:31 - 3:33 • 94%
Q7.5. What influenced this decision?

Speaker 2 • 3:34 - 3:35 • 81%
Cross ventilation?

Speaker 1 • 3:36 - 3:41 • 96%
Q8. Did the site orientation play a role in your energy efficiency strategy?

Speaker 2 • 3:42 - 3:57 • 95%
Yeah, a bit, but in our project, we wanted to be adaptable to any site and a lot of orientation, so no, but we still consider it. Consider it a bit. In terms of sun angles,

Speaker 1 • 3:58 - 4:03 • 93%
Q9. what passive strategies have you used? Was it the one you just mentioned

Speaker 2 • 4:03 - 4:15 • 96%
Sun shading, cross ventilation, thermal infiltration, the envelope and daylighting Daylighting

Speaker 1 • 4:17 - 4:22 • 98%
Q9.5. Which one do you think made a big difference with energy efficiency?

Speaker 2 • 4:25 - 4:28 • 95%
The cross ventilation with our design.

Speaker 1 • 4:29 - 4:33 • 97%
Q10. How did your design change based on feedback from professors or peers?

Speaker 2 • 4:37 - 4:55 • 97%
We decided to break up the modules that we originally had. It was kind of just big blocks because Professor Chen had told us that we needed some community spaces, so we split it up, and that allowed for more ventilation and comfort among users, and occupants.

Speaker 1 • 5:02 - 5:03 • 98% What
have you used? Softwares?

Speaker 2 • 5:05 - 5:08 • 98%
Yeah. Climate consultant. Climate studio.

Speaker 1 • 5:09 - 5:15 • 97%
Q11. Did any unexpected challenges occur with the software you used during the modeling process?

Speaker 2 • 5:17 - 5:21 • 98%
Not really, no. We just made like some slight tweaks based on the results.

Speaker 1 • 5:21 - 5:27 • 92%
Q12. Do you feel these softwares provided a clear understanding for your design decisions?

Speaker 2 • 5:30 - 5:35 • 96%
Yeah, they're helpful in seeing how successful your strategies are. <affirmative>.

Speaker 1 • 5:37 - 5:44 • 97%
you're part of the performance team. **Q13.** Which other teams did you closely work with?

Speaker 2 • 5:47 - 5:59 • 98%
I wouldn't say we closely worked with any other teams, but we did take information from others, like the envelope group or the housing redesign group, which is what made some tweaks to ours.

Speaker 1 • 6:00 - 6:04 • 93%
Q14. How did collaboration with other teams impact your work on the project?

Speaker 2 • 6:07 - 6:19 • 96%
Their in-depth analysis of their sections allowed us to avoid doing all of that work ourselves. So, we just took what we needed from some other groups and used it for hours.

Speaker 1 • 6:19 - 6:25 • 96%

Q15. How did the workflow between the team manifest?

Speaker 2 • 6:26 - 6:28 • 98%
Like within the team or between other teams?

Speaker 1 • 6:29 - 6:30 • 84%
with the other teams.

Speaker 2 • 6:33 - 6:41 • 94%
It wasn't much like direct contact, it was mostly like looking at their sources or their presentations. that was fine.

Speaker 1 • 6:41 - 6:42 • 98% And
what about within the team?

Speaker 2 • 6:51 - 6:57 • 93%
Within the team? Just a lot of collaboration sitting next to each other and brainstorming. It ended up being fine.

Speaker 1 • 6:58 - 7:02 • 98%
Q16. How did you communicate with the other teams?

Speaker 2 • 7:05 - 7:10 • 89%
Just through their presentations. I'd look at their information and say what was helpful to me.

Speaker 1 • 7:18 - 7:24 • 98%
Q17. Do you think working as part of a team influenced your understanding of energy efficiency?

Speaker 2 • 7:26 - 7:33 • 98%
Yeah, because we both had different perspectives on what would work or what we shouldn't do

Speaker 2 • 7:39 - 7:49 • 95%
having different opinions and different past knowledge of energy efficiency.

Speaker 1 • 7:49 - 7:54 • 98%
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 7:58 - 8:17 • 96%
How important energy efficiency really is. I hadn't considered it that much in the past projects. And yeah, it is really in-depth in some areas, but there are also a lot of other strategies you can easily incorporate. It doesn't take too much time.

:

Participant 2

Speaker 1 • 0:00 - 0:22

I'm doing it for my thesis, your personal information will not be on my thesis, it's just the info that you're going to share during the interview.

Q1. At the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies? Out of 10?

Speaker 2 • 0:24 - 0:35

four or five, I thought I understood it but then not to the depth that we went into this semester.

Speaker 1 • 0:35 - 0:38

Did you learn about any of them before?

Speaker 2 • 0:38 - 0:49

vaguely, I, we had various vague, I was when our introductory class about it, we learned just the baseline of how to do it. not a true understanding of it.

Speaker 1 • 0:49 - 0:50

Do you remember the class name?

Speaker 2 • 0:52 - 0:57

ESA. But it was also just two years ago.

Speaker 1 • 0:57 - 1:02

Q2. What were your initial thoughts about achieving net zero energy in the project?

Speaker 2 • 1:04 - 1:16

I was a little nervous. It, I feel it seemed a little harder than it actually was
oh, how are we gonna make net zero? But then as you learn more about it, it seems it can be simply done.

Speaker 1 • 1:16 - 1:21

Q3. Okay. How did your understanding change as the project progressed?

Speaker 1 • 1:29 - 1:55

Before I thought it came down to all what the wall material was and I didn't realize how much it natural weather patterns and things that really take into account depending on where you are.

:

even how, how much? even daylight or the amount of thermal, what am I trying to say, the amount of daylight you get or wind direction can really change the way your building can work.

Speaker 1 • 2:00 - 2:07

Q4. Was there a specific moment or lesson that significantly shifted your perspective for the energy efficiency?

Speaker 2 • 2:07 - 2:37

Yeah, just simply I remember I put in the building, and with certain windows, the energy efficiency plummeted to nothing. And it's crazy how the whole wall was completely energy efficient, but just the wrong window changed the statistics completely. it was worse than a normal house having a certain window and then all of a sudden you put in a double pane something and it changed it to net zero. seeing how every little thing is a huge deal.

Speaker 1 • 2:37 - 2:43

Q5. Which concepts did you find most challenging to understand?

Speaker 2 • 2:47 - 3:00

I think I truly how everything connects and how it's assembled can make a huge difference. air tightness and things that and how materials connect to each other, which I had never truly thought about in depth before.

Speaker 1 • 3:01 - 3:07

Q6. How did working on a real world project influence your learning experience compared to normal

Speaker 2 • 3:41 - 3:58

I think it actually made you, it made me put a lot more thought into it. Even looking up actual materials and things which in normal things you're just slapping a material on it.

Speaker 2 • 4:01 - 4:16

Also, I think the difference between any other project is that since it's actually going to be built, you put a lot more thought into it. I think even the energy analysis thing we did, I'll continue to use that now throughout, just after being in a realistic studio.

Speaker 1 • 4:16 - 4:27

Q7. can you describe what major design decision you made related to energy efficiency?

:

Speaker 2 • 4:32 - 4:34
I feel I wasn't fully in charge

Speaker 2 • 4 35 - 4:54
if we would've kept proceeding into it, I just had a lot of sun shading design strategies and things that after working with daylighting. Other than that, I think that's about it. But I know we all followed the same kind of thing in previous ones, narrow building to get ,

Speaker 2 • 4:55 - 4:57
Better cross ventilation,

Speaker 1 • 4:58 - 5:05
Q8. the site orientation play a role in your, in energy efficiency strategies?

Speaker 2 • 5:07 - 5:29
Yes. There are certain aspects, even in daylighting, the majority of your windows facing the south, and you want fewer windows facing the east and the west. And if they had placed the long end of the building to, say, the east or the west, they would have destroyed the way they could have placed the windows. So it **had a huge role.**

Speaker 1 • 5:29 - 5:34
Q9. What passive strategies have you used?

Speaker 2 • 5:36 - 5:56
We used cross ventilation in our strategies and then we also used solar gain. We used shading devices and then I think that's about it, passive strategies and then of course placement directionality of the home.

Speaker 1 • 5:56 - 5:59
which one do you think made a big difference in energy efficiency?

Speaker 2 • 5:59 - 6:13
Energy efficiency, definitely the placement of the home on my cardinal directions, and then window placement made a huge, huge role, especially in the daylighting analysis. I did <affirmative>. I think that's about

:

Speaker 1 • 6:14 - 6:19
Q10. How did your design change based on feedback from professors or peers?

Speaker 2 • 6 21 - 6:45
Our design changed, I would say mostly just from peers, I was in a weird thing where I had to go back to the design team a lot just 'cause at first everyone wants big windows and just wasn't, it didn't work with the net zero home. So I changed, we changed that and then I know they made, they added the polycarbonate wall so that made me change materials that we used for lighting and things that.

Speaker 1 • 6:55 - 7:00
Q11. Did any unexpected challenges occur during the modeling process with Climate Studio?

Speaker 2 • 7:03 - 7:21
I think in the first round, I definitely ran into some issues, not realizing exactly how all the materials worked and how to choose them and things. And then especially once we got more information from the envelope team later on, that helped a lot. So it made Climate Studio way easier once you have all that information.

Speaker 1 • 7:21 - 7:25
Okay. And how did you handle them? the challenges?

Speaker 2 • 7:27 - 7:47
I think it was a big enough group. So if I had a challenge with a certain thing, there's always someone to ask. Even other people in the studio might know more about Climate Studio or the materials we're using. And I even went to Todd sometimes, for example, to say there was no option for a polycarbonate wall in Climate Studio yet. You can tell what materials are the closest.
Speaker 1 • 7 47 - 7:49
Was there, was there an option or there

Speaker 2 • 7:49 - 7:59
Wasn't? There wasn't an exact option, but they did have some window plastics that, well I didn't even know it was some name I did, I never heard of, but Todd told me about it. So yeah.

Speaker 1 • 8:00 - 8:08
Q12. Do you feel these tools, Climate Studio, and other software provided a clear understanding of your design decisions?

:

Speaker 2 • 8:09 - 8:22
Yeah, I think they did. I think it made it very, I know they're not as intricate as another one we use bop, but for, say, daylighting, I think it did a great job. And for thermal I think it gives you a great basis to work off

Speaker 1 • 8:22 - 8:23
Why do you think that?

Speaker 2 • 8:25 - 8:35
I don't know. I think it, I don't, I don't know exactly what. Yeah. But say I think it's pretty accurate. you put in your exact location, you can put in your exact orientation of the building so easy to use.

Speaker 1 • 8:49 - 8:59
Q13.. Which team are you part of your performance team. Right? Performance. Yeah. And which other teams did you closely work with?

Speaker 2 • 9:01 - 9:06
I found us more closely working with the Envelope Team and then also Design Team

Speaker 1 • 9:06 - 9:11
Q14. How did the collaboration with other teams impact your work in the project?

Speaker 2 • 9:12 - 9:26
I think the collaboration was helpful. If anything, I think I was having issues with materiality and things that, I could go to the envelope team and they could help me and get exact measurements of everything.

Speaker 1 • 9:26 - 9:37
Q15. How did the workflow between the teams manifest.

Speaker 2 • 9:38 - 9:48
I think it was good. I think there was a lot of patience on waiting on say the design team so we could run things and then once we ran things we were, wait, now we need the envelope team to get back to us. I think everyone worked really well together.

Speaker 1 • 9:54 - 9:55
What about with your team?

:

Speaker 2 • 9:56 - 10:10
I think we all tried to split work as evenly as possible, which was nice. It was really helpful having architectural engineers on our team, too. They had a lot of influence on us.

Speaker 1 • 10:11 - 10:15
Q16. How did you communicate with the other teams?

Speaker 2 • 10:17 - 10:19
A lot of times, we just did it in person during class,

Speaker 1 • 10:19 - 10:26
Do you think working as a part of a team influenced your understanding of energy efficiency?

Speaker 2 • 10:28 - 10:40
Yes. I think I would've had a lesser understanding of energy performance if I wasn't on a team. Now, I think I learned a lot from working with other teams. Okay, and my team altogether.

Speaker 1 • 10:41 - 10:45
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 10:48 - 11:10
This sounds like it's going to be a dumb answer, but I think it's okay. Overall, I think your decisions matter, and you should really think about the future and not just build a building because it always looks nice. Of course, you can try to make efficient things beautiful, but also always think about energy efficiency and projects.

Participant 3
Speaker 1 • 0:01 - 0:21
I'm doing this for my thesis with Todd and I'm not going to share any personal information of yours.

Q1. at the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies? 0-10

Speaker 3 • 0:30 - 0:31 Maybe a
four.

Speaker 1 • 0:31 - 0:34
Where did you learn about them

Speaker 3 • 0:36 - 0:58
Some of them are common sense, right? Like sunlight is free heating, opening windows creates a breeze. Yeah, I learned a little bit about them in my mechanical classes, but it was mostly like the common sense stuff.

Speaker 1 • 0:58 - 1:02
Q2. What were your initial thoughts about achieving that zero energy in the project?

Speaker 3 • 1:07 - 1:15
I think it's a very interesting concept, but I think it's more of a

Speaker 3 • 1:19 - 1:38
Unachievable goal. I don't think that we were equipped before coming in to know how to do a completely net zero. So I think my understanding was more or less get it as close as possible, but I didn't think we could actually achieve a true net zero.

Speaker 1 • 1:39 - 1:43
.**Q3.** How did your understanding change as the project progressed?

Speaker 3 • 1:52 - 2:26
I definitely felt like we learned more about how to implement net zero strategies. We became more aware with the process, but I still maintained that I don't think we could have completely had a net zero building. I still think we were trying to get it as low as possible, but not a hundred percent. But I believe that we probably could get more to like 95% versus at the beginning of the semester, I probably thought we could get to about 70%.

Speaker 1 • 2:27 - 2:34
Q4. Was there a specific moment or lesson that significantly shifted your perspective about it?

Speaker 3 • 2:45 - 2:47 <laugh>.

No.

Speaker 1 • 2:48 - 2:52
Q5. Which concept did you find most challenging to understand?

Speaker 2 • 2:54 - 2:54 Hmm.

Speaker 3 • 2:58 - 3:16
For me, the storage of energy and the storage of different utilities are important. We need, I understand how we create things, I understand how we use things, but it's that in between. What do you do with all that when you aren't using it? That's the hardest for me to understand.

Speaker 1 • 3:17 - 3:23
Q6. How did working on real-world projects influence your learning experience compared to traditional academic exercises?

Speaker 3 • 3:32 - 4:07
It makes it feel more real in a sense. When you're not just doing the theoretical <affirmative>, when you're doing an actual project, you're gonna troubleshoot some stuff, some trial and error, which helps you learn a lot more. I think it also makes it easier to sort of understand what you're doing. It's not just this abstract concept. You don't, you know, you're not just learning one plus one equals two and then never see it play out when you're doing an actual design. I think it helps solidify your sort of learning about it.

Speaker 3 • 4:07 - 4:07

Speaker 1 • 4:09 - 4:20
Q7. Can you describe one major design decision you made related to energy efficiency?

Speaker 3 • 4:20 - 4:24
Yeah, I was more like Joe's assistant during that project.

Speaker 1 • 4:24 - 4:30
Yeah, it, it's like for envelope people, but maybe you know you have done something that's why I asked you, but if not, it's okay.

Speaker 3 • 4:35 - 4:37
I just helped check all this stuff.

Speaker 1 • 4:37 - 4:45
Q8. Do you think that the site orientation played a role in in energy efficiency?

Speaker 3 • 4:45 - 5:11
For sure. You're not going to want to put a whole bunch of windows on the south orientation because you'll have a lot of sunlight come in which raises the amount of heat, which means you have to cool it more. So I definitely think that orientation plays a major role in, especially the hvac. Lower loads means you don't have to create as much energy.

Speaker 1 • 5:14 - 5:18
Have you used any passive strategies or just doing be out like you haven't used passive strategies?

Speaker 3 • 5:22 - 5:32
I'm still really unclear on what passive strategies are, if I'm being honest. Like is it just sunlight, good trees, block sunlight, air flows through building,

Speaker 1 • 5:33 - 5:38
Basically using nature as an energy?

Speaker 3 • 5:38 - 5:57

but I have like we've taken that project back to our own classroom and so yeah, like especially the trees, using trees that blocked the sunlight in the summer. Bring sunlight in in the winter.

Speaker 1 • 5:57 - 6:07
Q10. How did your design change based on feedback from professor professors or peers or like be updated data or anything?

Speaker 3 • 6:12 - 6:35
There was definitely, the materials of the walls I think changed a couple times because Joe and I found that we had to find something super efficient. Window placements changed a lot because we told them that they couldn't have as many windows in the position they wanted to.

Speaker 3 • 6:40 - 6:55
The HVAC equipment changed a few times because the equipment they had was honestly, I think over it had had more capacity than it needed to have.

Speaker 1 • 6:56 - 7:03
Q11. Did any unexpected challenges occur during modeling? Process would be out,

Speaker 3 • 7:06 - 7:18
Some of the data was a little hard to find relating to specific like pieces of equipment or specific materials. It's not as intuitive as you would think it would

Speaker 1 • 7:18 - 7:20
How did you handle them?

Speaker 3 • 7:22 - 7:38
Research also had precedents for what they considered to be their standard values. So Joe and I inferred some from that. And we did some research on standard values if we couldn't find specific ones.

Speaker 1 • 7:38 - 7:46
Q12. Do you feel BEOPT and other softwares provided a clear understanding for your design decisions?

Speaker 3 • 7:51 - 8:20
In the way we used them? Not really. By the time we used our program, we were sort of out of the design decisions <affirmative>. But I do believe that they would be helpful, especially with all of the graphs and charts you have available and you can keep older versions of the project and put in newer ones. So I do think that it provides good feedback by showing graphically what different changes do to the energy usage and stuff like that.

Speaker 1 • 8:20 - 8:28
Q13. You were part of the performance team. Which other teams did you closely work with?

Speaker 3 • 8:30 - 8:38
The envelope team and the design team. And the systems team.

Speaker 1 • 8:38 - 8:44
Q14. How did you collaborate with other teams? How did collaboration with other teams impact your work on the project?

Speaker 3 • 8:45 - 9:15
We used the design team to create our baseline model. So we worked pretty heavily with them the first phase of the project so that we could get a baseline to show how our building was more

efficient. The envelope team, we worked with them a lot to make sure that the building was insulated, that heat wasn't gonna come in or, or leave the building. And then the systems team, obviously they have all of the equipment that's gonna generate heat, they need to make the building function

Speaker 1 • 9:16 - 9:20
Q15. How did the workflow between the team manifest?

Speaker 1 • 9:23 - 9:27
So it's like between your team and the other teams first and then within the team.

Speaker 3 • 9:32 - 10:05
So we got information, we tested things, we sent it back to them. Codes, they gave us all of the baseline codes. We tested that information. We didn't really give that back to them 'cause they didn't need it. <affirmative> envelope team, they said, Hey, we're using this. We took that information, put it in the model, and then we told them what that was like systems team, same thing. So yeah, we were just kind of a, not necessarily a sounding board, but we took that information, analyzed it, and then gave them the results.

Speaker 1 • 10:05 - 10:06
What about within the team?

Speaker 3 • 10:06 - 10:33
Within the team, really on the BOP side, it was just Joe and I and so we would put the information, Joe would get the information, we would put it into the program and then we would see what that would look like. And then a lot of the other stuff was done by the architects. It was really, it was really just the two of us. Yeah. Okay. On our own little island,

Speaker 1 • 10:33 - 10:39
Q16. You were the only engineers, right? Yeah, two. How did you communicate with other teams?

Speaker 3 • 10:42 - 11:02
A mix of emails. We used the OneDrive file a lot. we would put all of, we utilize that quite a bit to put our information in there. And then word of mouth, you have a question, you just go ask the person you want to discuss something, you just go talk to them.

Speaker 1 • 11:02 - 11:10
Q17. Do you think working as a part of a team influenced your understanding of energy efficiency?

Speaker 3 • 11:18 - 11:50

Yes. When you work as part of a team, it's not on you to know everything about everything So in a way I think it, I think it limited me a little bit in how I understand energy performance because I wasn't forced to know the ins and outs of everything. But I also learned quite a bit from the others when talking with them about how different sun paths affect a building, and all of this stuff.

Speaker 3 • 11:50 - 12:03
So I think, I think there are benefits and drawbacks to working on a team. I learned some stuff from everyone else, but I didn't learn as much as if I was like a subject matter expert.

Speaker 1 • 12:03 - 12:10
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 3 • 12:30 - 13:04

I think adaptability is a big thing. We were working in such a small little confine. We had planned out what we wanted to do, what our game plan was gonna be. And then by the time we were able to start our work, things were pretty much set in stone and so we had to adapt and figure out how we could best serve the team without necessarily providing that feedback loop that we thought we were going to provide. When we lost Dakota*, "an engineer in the performance group,"* who was the third engineer, we had to sort of readjust how we were gonna attack the whole problem.

Speaker 3 • 13:04 - 13:29
'cause he knew the most out of the three of us, there were constant changes and a lot of it was out of our control. You know, with the redesign group and the systems group, we couldn't really tell them what to do with their stuff. So it was mainly just learning how to take what we were given and make the best out of it.

Participant 4

Speaker 1 • 0:01 - 0:26

Just to explain the purpose of the interview, this will be for my thesis about the studio and energy efficiency.

Q1. At the beginning of the semester, how would you raise your understanding of energy efficiency and passive strategy?

Speaker 2 • 0:27 - 0:45

Two. I didn't know a whole lot about the different strategies. Well, I knew the strategies but I, I think I didn't know much about how to actually improve efficiency in terms of like thermal efficienc.

Speaker 1 • 0:46 - 0:48

And where did you learn about the strategies?

Speaker 2 • 0:49 - 1:06

We had a few classes, like environmental systems class a little bit during like just studio projects and studio professors advising against things. But you know, that was just a very basic understanding.

Speaker 1 • 1:07 - 1:11

Q2. What were your initial thoughts about achieving net zero energy in the project?

Speaker 2 • 1:12 - 1:39

It seemed really challenging because I think you don't see a lot of that. I think it's like a more new topic that's, you know, people are researching more these days. But usually like that hasn't been a focus in our past projects 'cause we're just focused on design. But to think about like the practical side of design was something that I had to like train my brain to think about.

Speaker 1 • 1:40 - 1:43

Q3. How did your understanding change as the project progressed?

Speaker 2 • 1:46 - 2:06

It was interesting to see like the scale of things like energy efficiency starts at, at a

really small scale like materials and like the joints of materials and how you put facades together and stuff. And yeah, so that kind of improved my understanding of it slowly.

Speaker 1 • 2:06 - 2:10

Q4. Was there a specific moment or lesson that significantly shifted your perspective?

Speaker 2 • 2:13 - 2:43
I think when working with the, the team that was in charge of the envelope design when they were putting together their buildup of materials, like their wall sections and roof sections, that was really interesting to see how just the, the positioning of materials can change thermal efficiency, whether it be for like walls or floors or roofs.
That was just something that I didn't think much about, but that was interesting to see..

Speaker 1 • 2:44 - 2:47
Q5. Which concept did you find most challenging to understand? <affirmative>?

Speaker 2 • 2:50 - 3:22
Probably all of the numbers related to the overall energy efficiency. I know we were looking into like the HERS scale and some other units and values for like annual energy efficiency and like monthly energy efficiency and all of that. just as somebody that in architecture hasn't worked too much with numbers and values like that, it was just a little bit challenging to get through.

Speaker 1 • 3:22 - 3:27
So you don't know if the numbers were right or wrong, like if they're efficient or not? If that's what you mean?

Speaker 2 • 3:28 - 3:29

Yeah.

Speaker 1 • 3:29 - 3:31
. So it's not about the units?

Speaker 2 • 3:33 - 3:43
Not, not really about, I just hadn't worked with those units before.. So I think I like didn't know what they meant until I looked through them a little bit more.

Speaker 1 • 3:54 - 4:05
Q6. How did working on a real-world project influence your learning experience compared to traditional academic exercises?

Speaker 2 • 4:05 - 4:37
Yeah, it definitely was a big learning experience. 'cause I think when you're like doing traditional studio projects, you kind of get away with like letting things slip. Like the certain, like small things don't really matter. Like all you're designing for is just like your reviewers. Like even if you don't

understand every detail of your building. But working on this project, because it's like a real-world project, we had to understand like every tiny detail of the house.

Speaker 2 • 4:38 - 5:13
And since it was actually gonna be built, we had to figure out how it was gonna be built. Everything from like structure and thermal efficiency and everything. So it was, it taught me a lot about the importance of like taking your time with a project and really looking at the finer details. And also from like an architect perspective, like sometimes we think that those details don't really matter, we just wanna make the big idea look good. But those small details actually contribute to making like the whole project be designed well.

Speaker 2 • 5:14 - 5:19
Small things are also part of the larger design and I think that's what it taught me. Every detail is important.

Speaker 1 • 5:22 - 5:31
Q7. Can you describe one major design decision you made related to energy efficiency?

Speaker 2 • 5:33 - 6:26
I know that one decision that the envelope team made was, I can't remember the specific insulation that they were using, but they used a specific insulation that was, you know, more efficient than like a generic kind. Another design decision that kind of came together last minute was the <u>polycarbonate</u> walls that I'm not sure yet if it was the best decision for thermal efficiency, but polycarbonate was the better decision for thermal efficiency compared to other translucent materials.

Speaker 1 • 6:29 - 6:33
Q8. Did the site orientation play a role in energy efficiency strategies?

Speaker 2 • 6:36 - 6:58
Yes. Because when designing towards the south facing, I think like the window placement and stuff, letting in Southern light versus Northern Light, I think in that, that way it played a role. I'm not quite sure what else the site orientation played a role in. Okay.

Speaker 1 • 7:18 - 7:27
Q10. Did you get a, like a feedback from professors or like your peers about the data you have put in for the thermal?

Speaker 2 • 7:30 - 7:53
Personally, I mean, we got feedback. I think other people didn't really know much about the programs that we were running either, so that was a little challenging. But when I showed the final graphs of how the energy had gone down, they were receptive to that or tried to see if you could make it go down more.

Speaker 1 • 7:54 - 7:57
Did it change like after you showed it to the professors

Speaker 2 • 7:58 - 8:01
After the final one? No, we didn't make any changes

Speaker 1 • 8:03 - 8:13
Q11. Did any unexpected challenges occur during the modeling process with Climate Studio?

Speaker 2 • 8:15 - 8:48
I think the biggest challenge was just figuring out how to work the model because, like, there were tutorials and stuff, but people around me didn't really know how to use that part of the model. So I think one specific challenge is like basically in Climate Studio you have to like build up your walls and your, your roofs and stuff with like layers of materials. And sometimes like a certain material wouldn't be available in the Climate studio database.

Speaker 2 • 8:49 - 9:11
So we weren't really sure like how to get a material that was similar or the same material so that it could be more accurate. So we ended up going with a material that produced a similar U-Value even though it wasn't the same material, and in hopes that that would be a more accurate result. It gives you the same results as the real material

Speaker 1 • 9:17 - 9:23
Q12. Do you feel these tools provided a clear understanding for your design decisions?

Speaker 2 • 9:25 - 9:56
I think so. It was an easier way for architectural students to understand things. It was a little bit challenging to get through, but it was the graphs that it provided, and the climate consultant was another tool that we used. The Climate Consultant provided possible strategies that we could use. It was just giving advice on things that we could use based on the climate, our climate type.

And so like the graphs from Climate Studio and BEopt were really nice to see how our design decisions were improving or reducing the energy efficiency. And then the climate consultant points that it gave, those were helpful in making the decisions too.

Speaker 1 • 10:16 - 10:24
Q13. You were on the performance team, which other team do you closely work with?

Speaker 2 • 10:25 - 10:45
We worked closely with the envelope team, because they were in charge of like the buildup of materials. And we also worked closely with the redesign team in relaying information and giving possible pointers on how they could improve their strategies as well.

Speaker 1 • 10:46 - 10:50
Q14. How did collaboration with other teams impact your work on the project?

Speaker 2 • 10:51 - 11:26
I think this was tricky because the, the Energy performance team was like one of the last people to receive information because we needed information, we needed final information from those teams that we were working closely with. And so it took a long time for them to get to their final information. Not to say that they weren't working, but it was just, I think they might have underestimated the amount of work that we had to do after they gave the information.

let's say like our deadline was approaching and they hadn't finished their part yet. We couldn't really do much until the envelope team had provided us with their material buildup and then I could input it into Climate Studio. So that was a little tricky.

Speaker 1 • 11:37 - 11:39
Do you think there would be a solution for that or?

Speaker 2 • 11:40 - 12:08
I think maybe like more incremental deadlines would be really helpful. It just seemed like it just, I think in these kind of team projects, one group is always just like waiting around, and then suddenly they're being thrust into like a really stressful time and they're just waiting and then it's stressful again. So there's like no in between. So I don't know what about a solution, but like maybe more incremental deadlines for other teams would've been helpful.

Speaker 1 • 12:09 - 12:18
Q15. How did the workflow between the team manifest or the teams or your team or the other teams?

Speaker 2 • 12:19 - 12:32
Okay. Yeah, like I said, it was a little bit challenging just because we had to wait so long to receive information. But once that information was received, it seemed like we were working pretty well

Speaker 1 • 12:32 - 12:34
what about your team Working

Speaker 2 • 12:34 - 12:56
Within our team? I think that was that. In the beginning it was a little tricky because just working with the fifth years, the fourth years and the engineers, it just seemed like we realized that we should have been communicating more <affirmative>. And then after that, I think once we got to a good flow with communicating with each other, it went pretty well.

Speaker 1 • 12:57 - 13:01
Q16. How did you communicate with the other teams?

Speaker 2 • 13:02 - 13:33
We usually had the engineers do a lot of the communicating with the envelope team in terms of the materials and how they were going to use the materials.
Especially with like the engineers were using BOPT a lot. I was the one, me and Frances were using Climate Studio, so they were doing a lot of the communication and we would email back and forth to receive like wall sections and stuff from them. So that was our method

Speaker 1 • 13:33 - 13:39
Did you communicate with them personally or like through email to receive the data or like group chat?

Speaker 2 • 13:40 - 13:52
Sometimes personally because when we were all in studio together it was easier to just go up to them and see what they were doing. But you know, outside of Studio Times, email is one of the better ways to communicate.

Speaker 1 • 13:52 - 13:59
Q17. Do you think working as a part of a team influenced your understanding for energy efficiency?
I,

Speaker 2 • 14:01 - 14:35
I think so because I hadn't worked on a team like this before and it would've been a lot to figure it out all on my own. And I think anyone, anybody else can say the same thing. But I remember one

point where everything kind of clicked for me was when I was comparing my climate studio results with Joe's BEOPT results, and he was explaining, you know, all the values and all the numbers, and you know how his results compared to mine.

Speaker 2 • 14:35 - 14:45
And so conversations like that that I've had within the team were really helpful in understanding 'cause it, I think it would've been hard to understand all of that on my own.

Speaker 1 • 14:46 - 14:51
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 14:52 - 15:12
I think the most valuable lesson was that energy efficiency is in the details of the project and small changes that might be invisible can increase like the overall thermal performance of the building.

Participant 5

Speaker 1 • 0:00 - 0:13

Just to explain the purpose of the interview, I'm doing this for, the thesis I'm having with Todd.

Speaker 1 • 0:14 - 0:21

Q1. At the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies?

Speaker 2 • 0:23 - 0:44

I'd say passive strategies probably **seven**. 'cause we had a lot of ESA classes that went over passive design. But as far as energy efficient systems Probably **three** or less. Three

Speaker 1 • 0:52 - 0:57

Q2. What were your initial thoughts about achieving net zero energy in the project?

Speaker 2 • 0:59 - 1:23

It seemed pretty doable because GA had a previous project that he had done, and I guess we have a lot of professors around here who can help us out with it. And it was an interdisciplinary studio, not just one studio working on the whole project. it seems pretty doable to me.

Speaker 1 • 1:23 - 1:28

Q3. How did your, how did your understanding change as the project progressed

Speaker 2 • 1:34 - 1:59

Yeah, so being on the envelope design team, I'd say we learned a lot more about passive design, mostly about how materiality plays into it. So if you have, let's say, stone flooring, that can be a thermal mass and stuff like that. But we had to change a lot in the final weeks of it, I would say.

Speaker 1 • 2:00 - 2:06

Q4. Was there a specific moment or lesson that significantly shifted your perspective?

Speaker 2 • 2:15 - 2:20

I don't really think so. I.

Speaker 1 • 2:20 - 2:26

Q5. Which concept did you find most challenging to understand?

Speaker 2 • 2:39 - 3:03

I'd probably say the roof detailing because that was something that changed a lot. They went from a green roof to a walkable roof to a non-walkable roof. But I don't know if it was really challenging.

It was more just the indecisiveness of the design team that made it difficult. But that was probably the most challenging thing that we had to do.
Speaker 1 • 3:04 - 3:15
Q6. How did working on a real project influence your learning experience compared to traditional academic exercises in normal studios
Speaker 2 • 3:16 - 3:48
so previously, I hadn't had any group projects, and coming from UMKC, we never did any group projects there either in our first two years. But we had, so in the first stage we had one partner, it was easy to
communicate with one person obviously, but as the group got bigger and bigger, it was harder to keep your line of communication and have everyone on the same page about everything. It kind of just made me realize how much or how important communication is in the design process.

Speaker 1 • 3:50 - 3:56
Q7. Can you describe one major design decision you made related to energy efficiency?

Speaker 2 • 3:58 - 4:28
Yeah, so I'd say we were in charge of the makeup of the walls, roof and floor. So one of our major design design decisions was to have continuous insulation around the whole building. And then we gave that to the energy team. They said that it was meeting the requirements. That was something we made early on. And then they haven't had any problems since then. The energy team never came back to us with a problem except when we added the polycarbonate wall.

Speaker 2 • 4:29 - 4:41
We had to change its thickness. But yeah, I think the continuous installation around the whole building set us on a good path from the beginning.

Speaker 1 • 4:43 - 4:46
Q8. Did the site orientation play a role in your energy efficiency strategy

Speaker 2 • 4:49 - 5:13
I don't think so because we, we didn't get to pick which materials went on which wall. That was also up to the design team. We just kind of got to do the makeup of the wall and we insulated all four sides of each unit. So. It wasn't related on or anything to do with that. So

Speaker 1 • 5:14 - 5:20
Q9. What passive strategies have you used and which one do you think made a big difference with energy efficiency?

Speaker 2 • 5:22 - 5:52

In my early project, I had a thermal mass in the floor, which I imagine would heat up the building. However, I don't think they included or our group didn't fight for a passive strategy. We were just coming up with the makeup of the walls. I feel they didn't; I think they added passive cooling into it.
Speaker 2 • 5:52 - 6:01
Passive with the natural ventilation through the unit . I'm guessing that made a big difference. I never personally saw that energy analysis so yeah.

Speaker 1 • 6:01 - 6:11
Q10. How did your design change based on feedback from professors or peers?

Speaker 2 • 6:12 - 6:55
Yeah, so since we're in charge of most of the unit's detailing, we had a lot of desk Cris with Professor Chen and ARD as well. We also had to go meet with Gibson to get a lot more feedback from him since he's made passive designs before, and he's in a studio that's doing that right now. But I'd say the foundation is something that changed a lot. Originally, we had designed it to where it would just be a perimeter footing 'cause that's what we were told, and then it became these movable footings, and it was on a parking lot, and how that attached to the unit changed a lot.

Speaker 2 • 6:56 - 7:14
And then I would say how the corners meet each other. So since we have three different materials on the whole unit, that was something that we had to think about. And that's something we're also dealing with now. Building the full scale model because we have all three of those materials in that one Z section that we're building. So just how those materials meet is something that changed a lot.

Speaker 1 • 7:20 - 7:26

Q12. what softwares have you used?

Speaker 2 • 7:27 - 7:43
In the initial stages, I used SketchUp, which was before this whole big group design. In this stage, I've been using the Revit model, yeah. I also use Adobe and stuff to line-weight specific drawings.

Speaker 1 • 7:43 - 7:49

Do you feel Revit provided a clear, clear understanding for your design decision?

Speaker 2 • 7:49 - 8:00

Yeah, I would say so. And it was a lot easier having one group model rather than having everyone work on separate things, which is something that happened in the previous two phases I feel .

Speaker 1 • 8:01 - 8:10
Q13. You're part of the envelope team. Which other teams do you closely work with or did you closely work

Speaker 2 • 8:10 - 8:43
I don't know exactly what team. The energy team, for sure. We had to give them all of our wall makeups and the thickness of all the insulation and stud thickness and everything so that they could run the simulation. So, definitely the energy team. And then, I guess, the redesign team redesigns just because they would come to us with material changes. And then the structure team was also, that was a secondary team we worked with.

Speaker 2 • 8:43 - 8:58
'cause many of the things they were doing directly affected the wall sections that we already had cut. <u>So if they would change how a window was placed or something, then that would change our entire makeup of What goes into it.</u>

Speaker 1 • 8:59 - 9:03
Q14. How did the collaboration with other teams impact your work on the project?

Speaker 2 • 9:07 - 9:37
I'd say the structures team was easy to work with so there was no problem there just I guess the engineers only came in two days out of the week, which is the hard part. But as far as the rest of 'em they, we pretty much just listened to whatever changes they had. I don't think, I mean, we were trying to advocate for things that we thought were best, but in the end, it was up to the design teams to decide it. So we listened to whatever they told us and tried to make it work.

Speaker 1 • 9:38 - 9:44
Q15. How did the workflow between the team, your, you, the other teams manifest?

Speaker 2 • 9:52 - 10:28
usually we would just make a wall section. We would present it to them and then they would, or to the energy team, they would tell us if it was good or bad. The envelope team didn't really base their decisions on our work. It was more the other way around. So yeah, that's where we mostly just listened to the EM or to the design redesign team. Yeah. And then the structures team, that was more of a back and forth thing. So yeah, I guess structures with back and forth, the energy team, we gave them stuff, and then the redesign team, we listened to their changes.

Speaker 1 • 10:28 - 10:29 What
What about within the team?

Speaker 2 • 10:30 - 10:56
Within our team we just use group meet chat and we kind of split up the drawings . So the drawing sheets we had split them up. Me and Kevin worked on the smaller unit drawings and then Rachel and Luke worked on the larger unit and that's nothing. Yeah, then we would just reconvene when we had a desk CRI and make sure things were reading the same way.

Speaker 1 • 10:57 - 11:01
Q16. how did you communicate with the other teams? Is it group chat or something?

Speaker 2 • 11:02 - 11:22
Just in studio. In studio, yeah. And also through teams there was some messages that were on teams. I know that didn't really become a huge thing that the whole studio used, but there was one main chat where people would put messages. the codes team had shared a file with us so we could all see.

Speaker 1 • 11:24 - 11:29
Q17. Do you think working as a part of a team influenced your understanding of energy efficiency?

Speaker 2 • 11:35 - 12:07
Yeah, in the beginning, our team started a huge mirror board so we just brought a ton of information in. So I guess in that way it was easier to get a wider understanding of it rather than just something that I was focusing on. in the initial stages I was just focused on insulation types, what goes inside the wall literally. And then other people were researching how cladding influences it . So by splitting it up it was we were able to cover a wider range.

Speaker 1 • 12:10 - 12:15
Q18. What do you think was the most valuable lesson you learned from this project?
Speaker 2 • 12:17 - 12:49
I would probably just bring that back to the communication aspect of it. And then I guess if you were just talking about building the model, I would say make sure you have all the drawings completely done before you start building. 'cause with this we, we have some small changes that we keep having to make . 'cause we didn't think about the type of bolts we're using or certain things that. Or when we had to cut the fiber cement, we didn't have the right saw blade for it and it set us back a bit.
Speaker 2 • 12:50 - 12:56
But I would just say communication is the main thing that I learned from this semester.

Participant 6

Speaker 1 • 0:02 - 0:12
Just to explain the purpose of the interview, I'm doing this for my thesis with Todd.

Speaker 1 • 0:14 - 0:21
Q1. at the beginning of this semester, how would you rate your understanding of energy efficiency and passive strategies Out of 10?

Speaker 2 • 0:22 - 0:46
six or a seven. It's really just about some passive strategies I've learned from like history really. That's what I would say. I know a little bit about like the stack ventilation systems and things like that. We've had, you know, classes about that but in terms of like more like advanced systems, yeah it was probably a little bit lower.

Speaker 1 • 0:47 - 0:50
Q2. What were your initial thoughts about achieving net zero energy in the project?

Speaker 2 • 0:51 - 1:15
I feel like a net zero was pretty achievable when I first heard it, I was told that it should be achievable based on the code that the 2021 IRCI think is, has laid out. So I figured it was pretty achievable but it does become kind of difficult to find information on some like more advanced strategy I found.

Speaker 1 • 1:15 - 1:20
Q3. How did your understanding change as the project progressed about energy?

Speaker 2 • 1:21 - 1:40
My understanding changed in that I think to achieve the net zero house you have to do like a lot of little things that build up to something larger. So you have to really focus in on like a lot of different systems working together and that is like the hard part.

Speaker 1 • 1:41 - 1:45
Q4. Was there a specific moment or lesson that significantly shifted your perspective?

Speaker 2 • 1:47 - 2:12
I think my perspective was really shifted early on when I was first talking about how to solve the insulation issues and how to use insulation and it became abundantly clear that that is actually like the first thing you wanna consider when the first thing I had looked at was cladding systems. When that is actually a lot less relevant for things the net zero you're gonna need the insulation mainly.

Speaker 1 • 2:13 - 2:18
Q5. Which concepts did you find most challenging to understand?

Speaker 2 • 2:21 - 2:53
Most challenging was definitely the buildup process, like how each system builds on top of the other. And I found it very difficult to figure out which system goes on top of the other. I think though like the synergies that are created between the different parts, I think I found really difficult to understand, like the insulation between the sheathing board and how much sheathing is required and the thicknesses that you want to have for each, each panel of the different systems and layering those things up is very confusing.

Speaker 1 • 2:53 - 3:03
Q6. How did working on a real project, a real world project influence your, your learning experience compared to traditional academic exercises like normal studios?

Speaker 2 • 3:04 - 3:36
I think it was really awesome because the scrutiny I think was a lot higher and so we were forced to sort of think about things in a lot further in more detail than I would normally think about them. But this created some problems, you know, just I was far out stripped of my knowledge, you know, kind of early on in some situations and so I had to really catch up to try and figure out and learn the solutions to these different problems that I never really had to to encounter before.

Speaker 1 • 3:37 - 3:44
Q7. Can you describe one major design decision you made related to energy efficiency?

Speaker 2 • 3:45 - 4:07
The major design decision was definitely to use the exterior insulation and try to make that continuous. I think that was the biggest decision we made because to achieve that requires a lot of coordination between the roof, the floor and the wall. And I think that was really ambitious to try and solve and that was definitely the biggest and most impactful decision.

Speaker 1 • 4:07 - 4:09
Q7.5 What factors influenced this decision?

Speaker 2 • 4:10 - 4:33
The factors that influenced that decision were the desire for the net zero home, net zero home. I think that not only getting that, but also I think doing the continuous installation, this exterior installation was also just probably the most advanced way to solve it and it felt like a, the most interesting path to it to, to try and challenge ourselves to figure out how to work.

Speaker 1 • 4:34 - 4:39
Q8. Did the site orientation play a role in energy efficiency

Speaker 2 • 4:40 - 5:12
For the site orientation? It, it really did. Only when we were looking at the windows, I would say when we were trying to decide what window we wanted, there is different windows that perform better at different orientations, on the site, but other than that it was more about the climates. I mean the site is of course in a climate zone and, and there's different climates in different areas. So that mattered from the start, and that influence, you know, how many, how much of the R-value we need. Yeah. And how much stuff like that. So that I would say is the extent of what the site influenced us specifically I think.

Speaker 1 • 5:13 - 5:18
Q9. What passive strategies have you used and which one do you think made a big difference with energy efficiency?

Speaker 2 • 5:19 - 5:49
The passive strategy that we tried to use was, I think, really the insulation. Our insulation is so, we had a lot more insulation than is typical on a project, right? You would have normally just had fiberglass or insulation between the stud cavity, but we had this exterior system and the fiberglass, and that was our strongest attempt, I think.

Speaker 1 • 5:51 - 5:53
Which one do you think made a big difference?

Speaker 2 • 5:53 - 6:13
The, the installation system made the, the biggest difference because it allows us to hold so much heat as well as keep the cold out, all those different things. And it can be used in conjunction with any passive system really with the, with the air and how that's coming through windows and things like that. So I think that the installation was definitely.

Speaker 1 • 6:15 - 6:19
Q10. How did your design change based on feedback from professors or peers?

Speaker 2 • 6:20 - 6:58
We got a lot of feedback 'cause especially early on, I think especially myself, I was focused on the incorrect things. I was focused on the cladding, like I said earlier, when that is, that actually matters a lot less when you're trying to figure out how to build the net zero home. The cladding was more about, I would say they wanted it for more visual orientations. I think that was more considered for

us and we really had to learn a lot about the insulation and the, and the sheathing and the, the different products that you can buy and the advantages and disadvantages of those things that took a lot of priority.

Speaker 1 • 7:00 - 7:03
Q12. Have you used any softwares or tools?

Speaker 2 • 7:05 - 7:12
We used mainly, we use Rhino and we use Revit. Revit was definitely the most helpful.

Speaker 1 • 7:12 - 7:17
Do you feel those softwares provided a clear understanding for your design decisions?

Speaker 2 • 7:19 - 7:23
Yes, I think Revit was definitely the most helpful I think. Yeah. Okay. Revit is definitely the best for this

Speaker 1 • 7:24 - 7:31
Q13. which other teams do you closely or did you closely work with? “He is with envelope team”

Speaker 2 • 7:33 - 8:17
I think we did try to work closely with the energy performance team. They were helpful in getting back some information about things we didn't think would work, but they were like, you know, they would actually work like the polycarbonate and so that was helpful to have some confirmation on some actual hard numbers that they ran. I did work a lot with, there was a lot of conversations with the redesign team I believe, where they were asking how different things are gonna be going together and like how, you know, I think the roof is, and there was some conflicts there with how tall the building had to be and those types of things that they were concerned about and that was like really in conflict with that we were trying to achieve to include some of the design elements.

Speaker 2 • 8:17 - 8:36
So there was a lot of back and forth about that and we think we did our best to solve those. And then I also worked a little bit with, I think it was, they are the, I forget the name of this team, they were the manufacturing team

they needed to know like what actual products we chose for the actual buildup. So they needed to know those things and so we communicated that some things were kind of vague, you know, when they'd come over and ask questions and we were like, they were like, oh what is this? And we didn't have the answers always figured out and so we had to kind of say, we think it's like this but we're not completely sure. So that was kind of a new challenge and I wasn't ready for it to not have a concrete answer so many times and be like, oh we're trying to figure it out.

Speaker 1 • 9:10 - 9:15
Q14. How did collaboration with other teams impact your work on the project?

Speaker 2 • 9:18 - 9:44
I actually liked how they impacted our work because when they introduced their intentions to us, I think that clarified to us what we needed to choose. And that was really helpful because there are so many options for building a house. So, narrowing the options down to what they wanted, what we actually wanted to achieve, and the numbers we thought were going to be sufficient was helpful. Cool. Working with other team members.
Speaker 1 • 9:44 - 9:49
Q15. How did the workflow between your team and other teams manifest?
Speaker 2 • 9:52 - 10:26
The workflow between the other teams was just very different than what other teams were doing. Other teams were so focused on producing drawings and other things that were maybe more speculative than what we were trying to produce. We were trying to make construction documents, right? So there were like, you know, details and so those were trying to, we were trying to make those realistic as possible and trying to make those as bright as possible. And so that sort of caused us to feel like we were gonna kind of a different boat.

Speaker 2 • 10:26 - 10:37
Oh okay. Other people were doing right. And so we kind of stayed on our side trying to make those construction drawings as real as possible and then they were sort of making these design decisions that were a little more up in the air sometimes.

Speaker 1 • 10:37 - 10:38
Q15.5 And what about within the team?

Speaker 2 • 10:39 - 11:11
I feel we had a great actual team. I think there was definitely a few conflicts, you know, and how we interacted a couple times, but actually I think most people's strengths and weaknesses complimented each other. Some people are more go get 'em and like just make a decision quickly. And some people were more like, oh we should stop and make sure that this is the right decision. And so the people that were maybe more timid that we're balanced out by the people that were go-getters, which is really nice to have someone that just goes in and gets it done and someone that's actually considering different things. So that's cool. I think the team dynamic worked out.
Speaker 1 • 11:14 - 11:16

Q16. How did you communicate with the other teams?
Speaker 2 • 11:17 - 12:00
It was mostly just a conversational, impromptu conversation. Hey do you wanna talk? Hey we have this problem, hey we have this problem and, and things like that. And they have, they would come to us with their questions and I think that was okay. It definitely could have improved if we took advantage of more channels or figured out a way to have a more collaborative online space where work was being placed in like information, like a database of information. I think that was kind of a, a problem 'cause whenever someone had a question they had to come and we had like our own documents that we were like organizing our decisions in, you know, they were making their own decisions and it wasn't like a one spot we could pull that information from.

Speaker 2 • 12:00 - 12:02
So I think we kind of messed up on that.
Speaker 1 • 12:02 - 12:08
Q17. Do you think working as part of a team influenced your understanding of energy efficiency?
Speaker 2 • 12:10 - 12:33
Yes, because there are still gaps in my knowledge that other people could help fulfill. I think that was the biggest thing with working in a team. There are things that you understood and you felt like you understood, but there were total, you know, gray areas that you didn't know what was going on and other people could kinda carry that and they would jump in the conversation and say, actually I think it's like this. And that was really helpful when you weren't sure what what was going on.

Speaker 1 • 12:34 - 12:38
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 12:40 - 13:14
Actual process of building a building and how these different parts actually are attaching and the different ways you can achieve that. 'cause there are so many different ways to achieve it, but just having the knowledge of, you know, one particular way that it could be achieved I think is super helpful. 'cause I really did not understand exactly how all of these different pieces are actually like nailed together, or you know, or what they actually do and how they are aligned properly to achieve their function, like shedding water or different things like that.

Speaker 2 • 13:15 - 13:22
It was really, really helpful to see how that is achieved, and I can actually visualize how that would happen now.

Participant 7

Speaker 1 • 0:00 - 0:21

Just to explain the purpose of the interview, I'm doing it for my thesis with Todd and your personal information will not be shared in the thesis.

Q1. At the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies? 0-10

Speaker 2 • 0:25 - 0:38

Four. I understood like passive strategies, but not necessarily how much like active systems and like intricacies of passive strategies

Speaker 1 • 0:38 - 0:40

And where did you learn about them?

Speaker 2 • 0:41 - 0:49

I learned them in a previous class. I think it was, I don't remember what it was called.

Speaker 1 • 0:49 - 0:58

Q2. What were your initial thoughts about achieving net zero energy in this project?

Speaker 2 • 0:59 - 1:14

I thought it was interesting, especially for such a small scale project, I felt like it would be pretty, almost pretty easy to do because there's such a small space that you have to work with, if that makes sense.

Speaker 1 • 1:15 - 1:18

How did your understanding change as the project progressed?

Speaker 2 • 1:21 - 1:45

So my understanding changed. I understood how to place the design on the site better and how to design specifically for certain strategies <affirmative>, but getting like a design team to do that and make it look good or make it look good was a whole another challenge.

Speaker 1 • 1:46 - 1:58

Q3. So was there a specific moment or lesson that significantly sha significantly shifted your perspective?

Speaker 2 • 2:00 - 2:03

I don't think there was a like a particular moment.

Speaker 1 • 2:03 - 2:08
Q5. Which concept did you find most challenging to understand?

Speaker 2 • 2:12 - 2:46
The most challenging to understand is from an architecture perspective, how all of the mechanical systems are working and how those can be like lend to energy professor, see that was the hardest to wrap my head around. But then once the engineering students explained it and like showed how that works and how they can work differently, it was actually really interesting.

Speaker 1 • 2:49 - 2:56
Q6. How did working on a real-world project influence your learning experience compared to normal projects like other studios?

Speaker 2 • 2:57 - 3:27
Working on like an actual project was interesting because I've, I've done like real projects from my internship, but working at it in a studio with people who haven't had that experience was interesting because there was a lot of having to explain to them, yes, we need to follow code or like we can't just ignore this small piece that we usually can in these theoretical projects because this is actually getting built.

Speaker 2 • 3:28 - 3:43
Thinking about how things come together and how that affects like the energy performance in this case is really important and then trying to get that through everyone else's heads.

Speaker 1 • 3:44 - 3:57
Q7. Can you describe one major decision design decision you made related to energy efficiency and what factors influenced this decision?

Speaker 2 • 3:59 - 4:20

So I worked with Jude a lot whenever he was trying to like work on like windows. So, helping him not just place windows but also determine which ones had applicable windows or how they were being shaded and how that might affect spaces, was probably the main thing,

Speaker 1 • 4:20 - 4:28
Q8. Did the site site, did the site orientation play a role in your energy efficiency strategy?

Speaker 2 • 4:30 - 5:07
So it played a role mainly because a lot of the windows and spaces that were placed, like were placed on the south facade, on purpose and then the small living module was placed on the southwest portion of the site and that would help with shading and providing a little bit more cooling to that bedroom on the west side in the summer, which is helping towards energy proficiency.

Speaker 1 • 5:08 - 5:15
Q9. What passive strategy have you used? Have you used any or was it, have you used any passive strategies? Like

Speaker 2 • 5:15 - 5:33
There's some sun shading in there. Okay. We have cross ventilation. I think that's okay. We used landscaping to assist in shading. One of the walls, there's a green wall on

Speaker 2 • 5:33 - 5:36
Landscaping southwest versa or southeast versa south.

Speaker 1 • 5:36 - 5:39
Q9.5. Which one do you think made a big difference with energy efficiency?

Speaker 2 • 5:42 - 6:07
I think the shading is going to provide the most towards energy proficiency because it is working to block the radiation hitting that direct wall or reaching through the window to hit the interior of the building. If you can shade that, it cuts down on how much your mechanical systems have to run.

Speaker 1 • 6:08 - 6:15
Q10. How did your design change based on feedback from professors or peers?

Speaker 2 • 6:16 - 6:51
We didn't really talk with professors. It was mainly the design team. I feel like the windows is what changed the most. The layout of the site and the designs themselves didn't change a whole lot. But moving and shifting like windows and the size of windows and even the simple like in setting the doorway where there would be like a window in there that helped to shade that kitchen space.

Speaker 1 • 6:52 - 7:05
Q11. Did any unexpected challenges occur during the modeling process with your climate consultant? Any of the softwares used?

Speaker 2 • 7:07 - 7:44
I don't think there was any huge problems. The only thing is that only the engineers knew how to use BOPT, and yeah, I guess that was just the only one that we ended up using outside of Climate Studio, and because of that, that's gonna make it harder for us to, if we need to run any more simulations, because the deadline got shifted. Yeah, I know they made like a guide on how to use it, but that's still another step.

Speaker 1 • 7:44 - 7:47
What about climate consultant?

Speaker 2 • 7:47 - 8:18
Yeah, I think that was modeling. It was okay. That was pretty simple and straightforward, but applying the wall assemblies and like roof assemblies, all of the systems that we used was challenging because we had to get information from other people that they might not have already had <affirmative> or knew how to even find. So some of the things I believe we had to assume I had, I don't know exactly.

Speaker 1 • 8:28 - 8:37
Q13. Which team are you part of in performance,
And which other team did you closely work with?

Speaker 2 • 8:38 - 8:50
I worked with the envelope team and the redesign team the most. I think those are the only two that we really worked with.

Speaker 1 • 8:51 - 8:54
Q14. How did collaboration with the other teams impact your work on the project?

Speaker 2 • 8:56 - 9:27
Collaboration with them made it run smoother when there was communication. If Jude and Anya were having design changes on the windows, for example, they had three different iterations at least sitting near where that conversation was happening. This allowed me to understand, okay, we're creating this model now, but it's going to change, and so maybe we should shift and wait.

Speaker 2 • 9:27 - 9:35
That way we get more accurate results. And then the envelope team was really important.

Speaker 2 • 10:05 - 10:24
Oh, the envelope team was important because they were giving us all the materials that were going into the wall and the the R values. So just kind of keeping updated with them and they provided us with a spot where they were doing all of their updated wall assemblies. So that was great to be able to check in on that. So cool.

Speaker 1 • 10:28 - 10:37
Q15. How did the workflow between the team manifest? How did it, the two teams and your team.

Speaker 2 • 10:37 - 10:56
The redesign team and our team was primarily because I, I have a seat right next to Jude and so I'd be working on something and then I would overhear change on this and Oh yeah.

Speaker 1 • 10:56 - 11:00
What about with your team?

Speaker 2 • 11:02 - 11:36
Communication with our team was a little rocky at times. To say the least, but I think we did all right. So, okay. I don't know, it was hard. The, there was like two people over on like in the center of the room. I'm on the edge and there was another person not quite in the center but like still near them and unless I went straight to them to ask something, I wasn't hearing anything.

Speaker 1 • 11:38 - 11:43
So do you think if you sit next to each other, like the whole time would be better?

Speaker 2 • 11:43 - 12:04
Sometimes? Possibly. I think that would definitely be helpful. That's why whenever I had work that I could be doing on my laptop, I would take it over there so I could sit near them and understand what was going on. Still <affirmative>, but there's sometimes that I just have to be at my workstation, so. Okay.

Speaker 1 • 12:06 - 12:09
Q16. How did you communicate with the other teams? Like

Speaker 2 • 12:10 - 12:27
<u>Mainly like in person</u>, just going over them and asking like whatever question I had
, it was a lot faster than like sending them a text or sending them an email. If they're in class, I would just go over there and if they had a minute, ask 'em a question and then move on.

Speaker 1 • 12:28 - 12:33
Q17. Do you think working as a part of a team influenced your understanding of energy efficiency?

Speaker 2 • 12:38 - 12:53
I think it, I think it definitely helped because it put me in a situation where I had to understand what I was doing enough to teach another person <affirmative>. So that was helpful.

Speaker 1 • 12:54 - 12:59
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 13:01 - 13:26
I think the most valuable is I being able to not only manage time, but communicate to others how I'm managing my time so that things can move in a smoother path, I suppose Communication was definitely a huge thing.

Participant 8
Speaker 3 • 0:01 - 0:18
the purpose of the interview is I'm doing this for my thesis with Todd and I'm not going to share any of your personal information.
Q1. At the beginning of this semester, how would you rate your understanding of energy efficiency and passive strategies out of 10?

Speaker 2 • 0:23 - 0:24

Two or three.

Speaker 3 • 0:24 - 0:26
Did you learn about them anywhere?

Speaker 2 • 0:27 - 0:28

no, we hardly learn anything about them. Before the studio,

Speaker 3 • 0:36 - 0:40
Q2. What were your initial thoughts about achieving net zero energy in the project?

Speaker 2 • 0:42 - 1:13
I thought that it was very attainable, given the size of our project. However, the conflict I felt like we always ran into was that we wanted this to be a house for low income or I guess the, the missing middle as it was always referred to. But then we're specifying $30,000 budgets for solar panels. Yeah. Which those two things are just realistically never going to happen. So just, just kind of the conflict from there.

Speaker 3 • 1:15 - 1:18
Q3. How did your understanding change as the project progressed of energy and passive strategies?

Speaker 2 • 1:23 - 1:56
I was learning a lot more about what affected, like what the, what the weight of all of our decisions were. Certain things, like since I worked directly with the energy model, some things I could kind of fudge an answer on. 'cause I was like, well, it doesn't really matter what decision we make; it's ultimately not gonna affect it that much. Whereas with some people who I worked with, like the HVAC people, I worked very closely with them 'cause I knew that their decisions were going to heavily impact the project. So, learning more about the weight and what gravitated more toward the project.

Speaker 3 • 1:57 - 2:07
Q4. Was there a specific moment or lesson that significantly shifted your perspective about energy efficiency and acid strategies?

Speaker 2 • 2:11 - 2:23
No, nothing that I can really recall. I think I was pretty driven towards that for most of the project. But I, yeah, I think my mentality on that was the same for most of it.

Speaker 3 • 2:24 - 2:27
Q5. Which concepts did you find most challenging to understand?

Speaker 2 • 2:37 - 3:13
In trade. I'm a mechanical person, not an electrical person. So working with the solar team was interesting 'cause like I understand how solar panels work and I understand generally speaking how they're measured, like performance wise. But then trying to like optimize that was something that I didn't really know a lot about. I'm trying to think what else. And then some of the, some of the daylighting stuff, like I still don't really, I didn't get into the weeds of it, like some of the other people on the energy performance team.

Speaker 2 • 3:13 - 3:25
But that stuff's interesting and I still don't really understand it, but I still struggle with it obviously 'cause I don't know much about it. Again, I didn't have to do it so.

Speaker 3 • 3:27 - 3:33
Q6. How did working on a real world project influence your learning experience compared to traditional academic exercise,

Speaker 2 • 3:35 - 3:53
Exercise? I think this specific project was not incredibly productive. I think other real, real world projects where there's not 30 engineers and 40 architects working on the same thing would be a lot more productive.

Speaker 3 • 3:55 - 4:00
So increase of engineers basically?

Speaker 2 • 4:01 - 4:07
Decrease everything. Decrease everything I want. I want like five engineers, maybe 10 architects. Max

Speaker 3 • 4:07 - 4:18
Q7. Can you describe one major design decision you made related to energy efficiency

Speaker 2 • 4:20 - 4:26
Envelope was one of the more impactful things that I worked with the envelope team on.

Speaker 3 • 4:26 - 4:29
What factors influenced the decision you made

Speaker 2 • 4:32 - 5:05
In the end? And they might have changed this since we left the project, but just consulting with them on different materials. And then there were some preconceptions I had about some materials on how easy they were to implement. But in the end we ruled out a decent amount of them either due to difficulty of installation or they just weren't, they weren't applicable in middle of the Midwest..

Speaker 2 • 5:06 - 5:16
Like you think, oh, the only thing I care about is the R value of the material. Which from an energy performance perspective, yes. But from a whole building perspective, you don't always think about.

Speaker 3 • 5:18 - 5:23
Q8. Did the site orientation play a role in your energy efficiency strategy ?

Speaker 2 • 5:26 - 5:36
Not really. Since we knew where we were gonna be. For gateway project, we knew exactly how we were gonna be placing it. So not really.

Speaker 3 • 5:38 - 5:39
Q9. Have you used any passive strategies?

Speaker 2 • 5:47 - 5:54
In our original design, yes. Okay. Those slowly got phased out as we continued 'cause it just wasn't

Speaker 3 • 5:55 - 5:57
What, what passive strategies have you used?

Speaker 2 • 5:57 - 6:33
Like natural ventilation? The, the, I mean the daylight, like all of that was considered, don't get me wrong, but I, I never saw like kind of like with the daylighting thing, like I never worked directly with

them on a lot of it <affirmative>. I just kind of, they would give me the results and I'd go with it. Yeah. And it seemed as we went along, like results were being implemented, but they weren't at the level of if we are really, really honing in on net zero, like we would do something different.

Speaker 3 • 6:34 - 6:40
Q10. how did your design change based on feedback from professors or peers?

Speaker 2 • 6:41 - 7:03
The professors were very adamant about wood and what wood and wouldn't work. So I did not do a lot of the design itself. I simply did the energy performance results and like I said with the HVAC and the, and the envelope, those were the two main components that I'd say I influenced.

Speaker 3 • 7:03 - 7:11
Q11. Did any unexpected challenges occurred during the modeling process?

Speaker 2 • 7:15 - 7:52
There was a learning curve in trying to do the optimization model, like trying to select different options and try and compare them. I'd say the biggest thing that was challenging was trying to make the results. Something that could be interpreted by someone who hasn't worked in BOP or hasn't looked at an energy model before. Which, if you look at our final drawings, we have the timetable of like how it got shaped over time and with each decision, how much that impacted the final outcome of our energy performance.

Speaker 2 • 7:54 - 8:05
That is not something that BEOPT can produce. And so trying to find where BEOPT can help with that is, was a challenge that me and the team had to work through.

Speaker 3 • 8:05 - 8:06
Q11.5 How did you handle the challenge

Speaker 2 • 8:09 - 8:37
Data input? It, it was a lot of like, I mean directly we, I went through and literally thought of every design decision. We went through the entire project, started with the baseline model and said, okay, here's our baseline model and let's make this one change, rerun it, let's make this change, rerun it, collect all that data, put it into a bar graph format, which is what's on the drawings. And that was what we found to be the most easy way to portray it.

Speaker 3 • 8:37 - 8:45

Q12. Do you feel the tools provided, like the beopt, autonomy CDU, provided a clear understanding of your design decision?

Speaker 2 • 8:48 - 9:11
Clearer than if we had nothing else? Sure. It, I think it, I, I think if we were be, I don't know, word this we're students. So we don't know exactly the repercussions of every decision we make. Still, it gave us a lot better understanding of what was happening every time we made a decision. Okay.

Speaker 3 • 9:13 - 9:20
Q13. So you're part, you were part of the performance team. Which other teams did you work closely with?

Speaker 2 • 9:21 - 9:26
Systems and envelope and then the main redesign team.

Speaker 3 • 9:26 - 9:31
Q14. How did the collaboration with other teams impact your work on the projects?

Speaker 2 • 9:36 - 10:10
Some of the teams were very open to input. Others were going based off what the professors had told them. And I can't really blame them for that as were students and this is a class and you go off what the professor says. But like, like the engineers, they, we all understood that we weren't getting harshly graded on this for the most part. So they were more open to feedback and that's why I spent like five or six hours working very closely with the HVAC designer who I'm best friends with.

Speaker 2 • 10:10 - 10:23
Yeah. To do that kind of to, to optimize that kind of stuff. But then the envelope team, it was more of a, they'd give me something, I'd give them something back. Very feedback loop ish.

Speaker 3 • 10:33 - 10:40
Q15. How did the workflow between your team and the other teams you just mentioned manifest the envelope? The design and

Speaker 2 • 10:41 - 11:12
The, we had an initial meeting with Gabbard and Professor M over how our general like structure was gonna go. I thought you were there for Yeah, that meeting I believe started with that. It really, I don't wanna, like, we didn't really stick to that ultimately. I mean it, I think there was just more work than we were anticipating.

Speaker 2 • 11:12 - 11:44

And so trying to stick to the schedule where we document everything along the way was just more upfront time commitment than we were anticipating. And then, I don't know, I think, I think we just, it was just more commitment than we were looking for. And so some of those things fell to the wayside as we went. I don't know how much that really impacted our relationship with other teams. I think we still fulfilled our role and giving feedback for most of the components of the design.
Speaker 2 • 11:44 - 11:50
But it's, it could be improved if we were engineers who were getting paid and cared.
Yeah,

Speaker 3 • 11:51 - 11:57
Q16. How did you communicate with the other teams?

Speaker 2 • 11:59 - 12:23
in person in studio, that was, I was very much on the initiative of trying to get everyone to use teams to communicate and share files. I failed so I got one person to use it and everyone else ignored me. Oh. And then they wonder where all the files went. Well, if we'd put everything on teams anyways.

Speaker 3 • 12:24 - 12:30
I've heard the teams a lot, like they wanted to use it, but nobody actually used it. So they just ignored it.

Speaker 2 • 12:30 - 13:03
Like there was a OneDrive, there was a team, someone made a Google drive for something. There's all the models on BIM 360, which some people have never used BIM 360. I mean like a lot of the architects of course haven't. But then the, even some of the engineers who haven't had really good internships, they haven't experienced BIM 360 either. And so they thought it was a file storage mechanism. So then also with our Revit models that are getting shared over the cloud, then you throw in just random stuff.

Speaker 2 • 13:03 - 13:22
It, there was just place stuff everywhere. The energy team didn't really care that much. 'cause we, I mean we're in kind of our own world. But everyone else who's trying to base all their decisions off everyone else's decisions and collaborate in that way, I know that wasn't a very streamlined process for them or anyone else. Okay.

Speaker 3 • 13:23 - 13:28
Q17. Do you think working as part of a team influenced your understanding of energy efficiency?

Speaker 2 • 13:29 - 13:54
There were new perspectives brought to the table every day—stuff that I overlooked, and obviously, it helped me in a lot of ways. Megan was very beneficial in doing some of the grunt work. And not, obviously, I did some of that too. But then we would both collaborate on the same stuff, and she'd find stuff that I didn't find and vice versa.

Speaker 3 • 13:56 - 14:00
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 14:19 - 14:50
there were a lot of things that went wrong and there, there was a lot to be learned from that. Not only from the professors, but just from how the students conducted themselves and how there was a lot of, I don't know a better word for it, but like just power mongering between the different parties. But no, I don't like, I, I learned stuff like if you, if you interview most of the engineers, they're gonna say they don't, they didn't learn a whole lot.

Speaker 2 • 14:50 - 15:17
I learned stuff. There was communication. The first project where it was like the 27 groups or whatever. I learned a good amount there. Whether it was about stuff I really care about or not. That's stuff for debate, but it, like, it's stuff I didn't know before. So Cool. There, there was stuff that I got out of it.

Participant 9

Speaker 1 • 0:00 - 0:19
just to explain the purpose of the interview, I'm doing it for my thesis with Todd and all your personal information will not be shared.

Q1. at the beginning of the semester, how would you rate your understanding of energy efficiency and passive strategies?

Speaker 2 • 0:20 - 0:51
One to 10? Yeah. I would say probably of <u>seven and closer to 10 with 10 being the best</u>. Seven because we did an environmental study class, the energy analysis, we did a lot of energy data and I knew about different passive systems solar panels, and I've thought about it, but I've never used it to the scale of this in terms of how the wall assembly was made and the way the envelope of the building could help. I've only ever thought about systems that are doing it rather than the design of the building.

Speaker 1 • 0:52 - 0:57
Q2. What were your initial thoughts about achieving that zero energy in the project?

Speaker 2 • 0:58 - 1:24
I thought it was gonna be heavily dependent on the design. If the design of the building in terms of the form was well thought out, I feel it'd be easy . But if you, depending on what we decided to do in terms of how the building was formed, it was gonna be making it easier or harder. So if I was doing the two separate buildings, it might be harder cause there's more of the building exposed to each side of elements. But I feel it's not hard or impossible. Okay.

Speaker 1 • 1:25 - 1:29
Q3. How did you, how did your understanding change as the project progressed?

Speaker 2 • 1:30 - 1:31
Understanding of what

Speaker 1 • 1:32 - 1:34
Energy efficiency and passive strategies.

Speaker 2 • 1:34 - 1:54
I think it's definitely changed a bit. Doing research with the envelope and figuring out what was the best for the wall systems definitely changed the, depending on different things we can do for it. In

my mind I thought there was only a set, a set way to do it or there's a very set way to do it versus way we did it and it's, I really opened up a little bit
Speaker 1 • 1:55 - 2:02
Q4. Was there a specific moment or lesson that significantly sh sh shifted your perspective?

Speaker 2 • 2:05 - 2:23
Not really. I guess the only thing that kind of shifted is when we actually started getting the wall section down and getting the data back and realizing how valuable it was. When we started calculating our values, it was neat to see how much it would change just by taking one simple thing out. And that's kind of the turning point, I would say

Speaker 1 • 2:24 - 2:28
Q5. Which concepts did you find the most challenging to understand?

Speaker 2 • 2:31 - 2:59
Probably in terms of just envelope wise, I would say probably just the connections to between the floor, the wall, and then the wall and the roof. trying to figure out that because that's a break in the system theoretically and you have to figure out how are we putting that together while still keeping it continuous and trying to keep as little bridging a gap and stuff like that. because those are the points where air tends to get in the most or the weakest points of a building. Okay.

Speaker 1 • 2:59 - 3:07
Q6. How did working on a real-world project influence your learning experience compared to traditional learning exercises in normal studios?

Speaker 2 • 3:08 - 3:42
I think it's definitely different and as I've even, I've been talking to other people from other studios and stuff, they definitely agree that the studio would've been a fun experience and it was definitely intriguing. that it was not everyone trying to do one project 'cause then the stress on us wasn't as much, so this wasn't as much of a stressful studio as more a little more laid back. But it was also the thing you are kind of in the real world, and the standard studio we don't have, not everyone works on one project through the entire thing. It's in a real world. You have multiple people working on one project and this studio.

Speaker 2 • 3:42 - 3:48
So there was definitely a lot of relying on others and experiencing as it would be in a real studio environment.
Speaker 1 • 3:48 - 3:56
Q7. Can you describe one major design decision you made related to energy efficiency

Speaker 2 • 3:57 - 3:59

Speaker 2 • 4:00 - 4:30
I would think the major thing is just by doing a continuous insulation. I feel that was the biggest help because continuous insulation alone helps provide a lot of thermal things, and we don't need to go as deep or heavy on the cavity insulation or bad insulation. Whereas we said, we went very heavy and expensive on the exterior but cheaper on the interior. So that way that the overall system that if your interior cavity is not as well insulated then you still have a very good insulative material on the outside.

Speaker 1 • 4:31 - 4:34
Q7.5 what factors influenced this decision?

Speaker 2 • 4:34 - 5:01
I think it came down to what, just what, what we wanted to do in terms of materials and the thickness of the walls, and when looking at all our different systems, we saw that the continuous installation would be the best benefit for no matter what we did interiorly, what we did stud wise or installation wise. It seems every one of our designs had continuous installation out of 'em and so that's what kind of led to us doing that as the main one.

Speaker 1 • 5:02 - 5:07
Q8. Did the site orientation play a role in your energy efficiency strategies?

Speaker 2 • 5:08 - 5:42
Us personally, no. Okay. As the envelope, no matter which way the building was orientated, it had to be the same energy efficiency. So they'll basically design the buildings if it was all just one mass, no matter where it was just, it was designed the same. The only difference would be if it was a window, but we weren't in charge of where the windows were, we were just in charge of how the wind, how the windows were designed or what type of windows we did. And so it kind, we weren't necessarily heavy on the orientation of the building, it was more just treating the building as if it was just standing freely in the middle of nowhere and or all sides were equal.

Speaker 1 • 5:45 - 5:47
Q9. Have you used any passive strategies?

Speaker 2 • 5:53 - 6:25
I don't think we did. The only thing, a passive strategy that we would've, that we would've done is just kind of natural ventilation. But that wasn't as much of us. That was more about the design team where they window placement and stuff. We were just making sure the walls, the kind of the

makeup of the walls and roof and we didn't really do any breathability in the roof or floor. It was kind of with that continuous insulation, it kind of really kept everything in it sort of, it sort of the continuous installation sort of acted as a barrier, buff barrier, not necessarily as a buffer a barrier so that basically it's prevent anything from outside from coming in.

Speaker 2 • 6:25 - 6:31
And so the only way it would be coming in would be through the windows, but we weren't in charge of where the windows were going. .

Speaker 1 • 6:33 - 6:36
Q10. How did your design change based on feedback from professors or peers?

Speaker 2 • 6:38 - 7:06
It changed a little bit. I feel overall, again, we said, initially, all of our ideas kind of did continuously, and I feel from the beginning we always, that's what we had, and that never really changed. The only thing that really changed was the way it was mounted or the way that we tackled stuff. the smaller things the thicknesses of materials and the exact type of material is what would change. But in the end, it would always be continuous with the six-inch stud.

Speaker 1 • 7:08 - 7:10
Q11. Have you used any softwares

Speaker 2 • 7:11 - 7:22
Personally? No.

Speaker 1 • 7:23 - 7:30
Q13. You're part of the envelope team. Which other teams do you closely work with?

Speaker 2 • 7:30 - 8:01
We worked heavily with the redesign team. Both. Both teams, the Kansas City and the main design redesign team, the systems team and probably the, I think it's called their environmental team. Basically, the redesign team would give us a design, and then we would have to take the system that we came up with and incorporate it into that; how we incorporated it would then get passed on to the environmental team or the net zero team, basically. And they calculate it and see what was wrong and we had to change it.

Speaker 2 • 8:02 - 8:15

But basically what we did also depended on the systems team because they needed to know how much room they had for certain stuff. And it was more towards the beginning with the structures, making sure that they knew how much room in the wall they had to work with.

Speaker 1 • 8:15 - 8:22
Q14. How did the collaboration with other teams impact your work and the project?

Speaker 2 • 8:24 - 8:58
It's, it impacted a little bit. The environmental team probably had the most impact of anything or that re actually probably the redesign team did the most impact because they would come to us with different ideas or changes and we'd have to find a way to quickly fit it into it. Or they'd kind of, there was one day to , can we do this to the design? And we're, we didn't account for that so now we have to account for it. Yeah. They were kind of the biggest players that both hindered us. The design team? Yeah, the redesign team. 'cause they would come up with these weird wild ideas or these unique ideas that we'd never even thought of or never accounted for.

Speaker 2 • 8:58 - 9:21
So then we had to either scrap what we were doing or alter what we're doing to fit that. And then sometimes they would just lead to nothing. We would just, we'd do all the work but then they changed the right back. So then we had to undo it. The environmental team helped, did a little bit, but we, and sort of from the beginning our system was already pretty well insulative and we didn't have to really change much. I think that was really changing. It was windows or small stuff.

Speaker 1 • 9:22 - 9:29
Q15. How did the workflow between the other teams manifest? your team and with the other teams
Speaker 2 • 9:31 - 9:33
And what do you mean? How did the workflow manifest?

Speaker 1 • 9:33 - 9:38
how did the, how was the work with them? Was it, was it, easy, hard?

Speaker 2 • 9:40 - 10:02
I mean there wasn't much workflow with the intermixed between them. It was sort of them coming up to us, Hey, here's an idea we had, can this work? Or Hey, we're doing this to design what you have to redesign it. Or hey, what if we did this? Basically it was more about just coming up, coming up to us with ideas and then us just trying to change it. There wasn't a lot of actual, hey, work on work sort

Speaker 1 • 10:02 - 10:04
And how about within the team?

Speaker 2 • 10:04 - 10:36
Within the team it was you're saying how does the work divide well or it was divided well, in the initial beginning when we were doing research especially, we all kind of took a portion of it. So someone did, I did the wall roof, Jake did the floors, some people , and then we kind of divided it up and all did research on those specific systems and kind of focused on that. As time went on, we came together on ideas and just started looking over each other's ideas. But we were kind of all put each other on a certain pace so we can each do, we're not all trying to do one thing.

Speaker 1 • 10:37 - 10:42
Q16. How did you communicate with the other teams?

Speaker 2 • 10:43 - 10:59
<u>Literally just talking in the studio, just in person</u>. Didn't use, we didn't use teams at all. We didn't use anything else. You, anything we already chat we have is just in our own group chat for our own group. We didn't have any other communications just coming in the studio and them saying if they changed it or us asking if there needed to be anything else .

Speaker 1 • 11:00 - 11:05

Q17. Do you think working as part of a team influenced your understanding of energy efficiency?

Speaker 2 • 11:10 - 11:40
I'm gonna say a little bit, yeah. Because there were things that I wanted to do and there would be, I had a set in the mind of what I wanted to do or what I wanted, what I thought would be best for energy . And by working with a group, other people's ideas came in and whether they'd be they were for the best or the worst, different ideas helped kind of shape the design the way it is. And I feel we all kind of met, it came out, it would've came out better than it would've, it was just one person designing it because then one, only certain people have certain understandings of energy efficiency.

Speaker 1 • 11:41 - 11:47
Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 2 • 11:50 - 12:21

Hmm. I would just say coordination with others because there was a lot in the very beginning it was very slow, boring and there's just not a lot of communication going around between any groups and so it was just hard to do work. But once we got a design and communication really started to pick up, it was getting better. And I feel working with groups was helped you learn communication is key and that not to just sit around waiting for someone to tell you, you should probably go up and ask 'em and try actually to get, not, don't wait for it. Yeah. So time management maybe .

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Participant 10

Speaker 1 • 0 00 - 0:19

Just to explain the purpose of the interview, I'm doing this for my thesis with Todd and there your personal information will not be shared with my thesis. It's just like the answers you provide in you for the interview.

Q1. At the beginning of this semester, how would you rate your understanding of energy efficiency and passive strategies?

Speaker 3 • 0:23 - 0:26

Probably like a six out of 10.

Speaker 1 • 0:27 - 0:29

where did you learn those

Speaker 3 • 0:29 - 0:33

From last semester in the Gateway Decathlon.

Speaker 1 • 0:33 - 0:36

Any other classes

Speaker 3 • 0:43 - 1:04

Learned some in Gibson's ESA class a few years ago, very simple things. Just like thermal mass or like night cooling. Just really simple things.

Speaker 1 • 1:04 - 1:10

Q2. What were your initial thoughts about achieving net zero energy in the project

Speaker 3 • 1:12 - 1:42

Yeah, honestly I didn't have much of a reaction at all. I just kind of assumed that's what we would do. I guess one reaction is how is, like, how is that possible? , especially in like the climates that we live in.

Speaker 1 • 1:49 - 1:54

Q3. How did your understanding change as the project progressed about energy efficiency and passive strategies?

:

Speaker 3 • 2:00 - 2:26

through design. I started to think about window placement, how this would affect the building, and the use of energy, and the envelope team looked into a lot of insulation and different building strategies.

Speaker 1 • 2:27 - 2:34

Q4. Was there a specific moment or lesson that significantly shifted your perspective?

Speaker 3 • 2:41 - 2:47

I don't know. I say I've kind of been same throughout this whole semester.

Speaker 1 • 2:47 - 3:03

Q6. this is a real project, how did working on a real world project influence your learning ex experiences compared to traditional academic exercises like normal studios? Mm,

Speaker 3 • 3:04 - 3:34

It's been great. I think everybody should have a studio like this. Actually, building the thing has taught me so many things that I would not know if we weren't building it, even just simple framing. As architects, we just design and say, "Oh, these two pieces would go together," but when you're building that, well, how do they go together? What fastener are you using?

Speaker 3 • 3:34 - 3:41

And there's just so much more to it which is really helpful in understanding how things are built.

Speaker 1 • 3:42 - 3:50

Q7. can you describe one major design decision you made related to energy efficiency?

Speaker 3 • 3:51 - 4:04

We decided to use exterior insulation to get continuous insulation around the house, so we have less thermal breaks and better efficiency.

Speaker 1 • 4:04 - 4:06

What factors influenced this position?

Speaker 3 • 4:16 - 4:16

Gibson *"A professor not associated with the class"*

:

Speaker 3 • 4:21 - 4:23
Went to We talked to him this semester.

Speaker 1 • 4:24 - 4:29
Q8. Did the site orientation play a role in your energy efficiency strategy or no?

Speaker 3 • 4:30 - 4:32

No.

Speaker 1 • 4:33 - 4:35
What passive strategies have you used then?

Speaker 3 • 4:38 - 4:54
I'm not really sure because we're just kind of doing the wall buildup, and the energy team knows a lot about that. I think there was some like shading. Shading,

Speaker 1 • 5:09 - 5:15 *"Good Answer"*
Q10. how did your design change based on feedback from professors or peers?

Speaker 3 • 5:17 - 5:56
This semester was tough because Zhan, *"5th-year professor,"* and Gabbard, *"4th-year professor,"* gave their opinions on things. They both have very different opinions, and our team is two people from two different classes. So it was hard trying to please two different opinions.
Plus Gibson *"Outsider professor"* was telling us, this is actually how you do it, so that's been really hard.
I would say Gibson has been the biggest help through actually finding a good wall sect

Speaker 1 • 5:58 - 5:59

Not the two professors,

Speaker 3 • 5:59 - 6:27
No, but the feedback just wasn't as good. And for us, “the two main professors” would both say completely different things. So it's hard when you have two of you being graded by one and the other two being graded by another.

Speaker 1 • 6:27 - 6:36
Q11. Have you used any softwares?

Speaker 3 • 6:41 - 6:43 We
worked in Revit.

Speaker 1 • 6:43 - 6:47
Q12. do you think you provided a clear understanding for your design decisions?

Speaker 3 • 6:49 - 7:21
Yeah, I would say we liked using Revit because we can put that wall section into Revit, and it builds that wall for you. So if we had a quick change, we'd be like, "Oh, we want to use two-by-sixes instead of two-by-fours." Now, we can quickly make that change in Revit, and it generates it for us. So we don't have to go back into Rhino and change every single little line.

Speaker 1 • 7:22 - 7:31
Q13. you are part of the envelope team. Which other teams do you closely or did you closely work with?

Speaker 3 • 7:32 - 8:03
We work closely with the design team, mostly with cladding materials. That was the biggest thing we talked to them about, like what look do you want? We recommend these materials. Okay, what sizes can we do? We're not going to use just one material; we're going to use different materials. So where do we want these materials? Yeah, we probably worked with them the closest.

Speaker 1 • 8:04 - 8:09

Q14. How did the collaboration with other teams impact your work on the project?

Speaker 3 • 8:11 - 8:43

The design team impacted us because, I mean, the cladding on the building was changing, and we were always like, okay, well, where's this gonna go? I don't know, make a decision. I don't know if any other teams impacted us, but the landscape team actually impacted us because they wanted the decking in line with the seams of the building. So we did get impacted by them.

Speaker 1 • 8:48 - 8:55
Q15. How did the workflow between your team with the other teams manifest?

Speaker 3 • 9:03 - 9:35
It was all right. It was a little hard getting those final decisions. There was just so much back and forth , it's like, can you just make a decision already? I wish we had brought in the engineers a little later because I liked working with them. Yeah. But it was like maybe they didn't need to be at the very, very, very beginning

Speaker 1 • 9:35 - 9:37
Q15.5 And what about within the team?

Speaker 3 • 9:42 - 10:17
There's been one, one team member who's in my class. We work really well together. communication's good. We are usually on the right page. There's one the other class that can make it difficult to talk or just say different things. And yeah, it's, it can be difficult to communicate things. Okay. And not say them over and over again, but it's really not been bad.

Speaker 1 • 10:18 - 10:22
.**Q16.** How did you communicate with the other teams?

Speaker 3 • 10:24 - 10:35
Just in studio. There was never, yeah, we never talked to anybody through text or anythings. All in person.

Speaker 1 • 10:35 - 10:42
Do you think working as part of a team influenced your understanding of energy efficiency?

Speaker 3 • 10:46 - 10:58
Yeah, I think so. Because there's different ideas or somebody has done different research that you haven't, and so you're like, oh, I didn't know that was even an option.

Speaker 1 • 10:58 - 11:04

Q18. What do you think was the most valuable lesson you learned from this project?

Speaker 3 • 11:13 - 11:45

I'm going back to when we were working with the engineers. That really taught me how we actually work with the engineers because we will need to do that in the future. So how do I need to team up with the engineer to get a good end result? I definitely learned a lot about that. And how do I come across a problem? How do I go to that engineer and say, "Hey, there's this problem. Let's fix it together?"

Appendix C – Observation Notes

Observation Notes

Sept 30, 2024

- Studio Performance Research File

Oct 2, 2024

Energy Performance team structure file uploaded

- Goals set

Oct 14, 2024

Designing a model in Rhino for Climate Studio

Word document in one drive about energy efficiency research

BeOPT results for baseline model ready.

Information Needed for climate studio analysis file created “Information Needed”

Oct 16, 2024

Finished the model for climate studio, first time running thermal analysis. Used generic materials to get preliminary results

Raw daylight analysis, running it through 2 different times of the day.

PDF Daylight Analysis from climate studio on OneDrive (10/16/2024), Windows: Double Glaze

- sDA 30.6%
- ASE 28.7%
- Data collected from two separate times, 9:00 AM, 3:00 PM in September
- 3067 avg LUX

Oct 23, 2024

1- Decrease the amount of LUX for the daylight analysis by adjusting the windows
- Add shading devices

- Have overhang windows
- Refine all window sizes from 3x6 to 2x4

Preliminary results are sent by email as screenshots

Another daylight analysis was done by changing from double-glaze windows to triple-glaze windows, and the avg LUX decreased by 100

2- Received different layers of envelope from design team (7 different components for roof, 6 for wall, 5 for floor). Add the inputs on climate studio and run the thermal analysis, if the data was high, they will talk to the design team to change the layers and components to get lower results.
3- BeOPT: All data results are without solar panels
- Checking for errors and troubleshooting
- Problems with humidity control issues, high relative humidity ratio.
- Checking with HVAC people to decrease the amount of TONS
- Fixing problems with the model to have better weather conditions outcomes.
- Contacted a constructor from Saint Louis to check with the Baseline model HERS index
4- Solar panels are created, and the inputs will be added to BEopts for lower HERS score

Preliminary results from BEopt were sent to me by email

5- New model was created and sent to all members with new window sized and placement.

Oct 28, 2024

HVAC Team:

1- Had a discussion with the energy team to find another model for the heat pump unit to fit in the mechanical room. This is due to a unit clearance problem with the code where they need to have space for the clearance, which didn't happen with the previous model. This will not effect the energy results but might delay the progress of their work since they need to have the inputs of the new model.

Energy Performance Team:

1- Daylight analysis: running the new design after the change of the window sizing from the design team and changing the depth of the overhangs for new results.

2- The formula used to find the new depth of the overhangs is: Projection (P) = Glazed Opening Height / Factor Based on Latitude ➔ P = H/F
3- Thermal Analysis: - Last week they got 28 EUI for both Modules, Today they worked on the small module and got 37. This is because they changed the COP from baseline to the real number and added hot water inputs for hvac.

Oct 30, 2024

Performance team: A new model was sent by the design team with refined window sizes, they changed the 2x6 slub walls to polycarbonate walls, and they widened the mechanical room for the heat pump based on the MEP team request.

1- Using Climate Consultant Software to look for the best passive strategies based on the weather data and psychometric chart.
2- They are working on changing the width of the polycarbonate walls to see which is more energy-efficient, and then send the results to the design team to finalize the width of the polycarbonate wall
3- They stopped doing the thermal analysis since there won't be enough time to work on it. This is because the envelope team is taking tme to send the new materials from the new model, and it takes time to upload the new materials and layers for the thermal analysis. So, the member started working with the BEopt people to make a pdf file with all the previous and current inputs and results.
4- A new model was created and sent to another member for the daylight analysis. Same member was doing research on Saint Louis weather data for climate consultant, and been doing research on passive strategies for the building.
5- Previous passive strategies used: Sunshade, thermal gain, green wall
6- Current one: Sunshade, thermal gain, cross ventilation and openable windows, green wall.
7- Takeouts: Nothing was removed from the previous strategies they had, only new strategies sere added to the building to help improve energy efficiency.
8- A member started creating sun path diagram, sunshade diagram, cross ventilation diagram, and green wall diagram. These diagrams will help explain the how each passive strategy works and lowers the energy use
9- New Daylight Analysis on OneDrive file 10-30-2024, with comments about each given result.

Appendix D – IRB Approval Form

KANSAS STATE UNIVERSITY

collapse

Protocol:	**IRB-12588**	**Sponsor(s):**	
Committee:	IRB	**Sponsor Id:**	
College:	Col of Architec, Plan & Design	**Grants:**	
Department:	Architecture	**Agent Types:**	
Title:	ARCH 899.E	**Year:**	2025
Exempt/Expedited Category:	Exempt Category 1	**Risk Determination:**	

Protocol-Site

Site(s):	**Various - SBR - IRB**	**PI:**	**R Gabbard**
Status:	Exempt	**Additional:**	N
Approval:	March 4, 2025	**Expiration:**	**Exempt**
Initial Approval:	March 4, 2025	**Other Expirations:**	
Inactive Date:			

Protocol-Site Contacts (1)

collapse

Name	Role
Bader M M H Alshawaf	Responsible Graduate Student

Reference xForms (1)

collapse

Form	Identifier	Stage	As Of	Ref Active	Inactivated
IRB Application for Approval	R Gabbard	Complete	03/04/2025 10:31 AM ET	03/04/2025 10:31 AM ET	

Events (1)

collapse

Event	Att	Instance/UDF	Start	Complete
IRB Initial Submission	6		03/04/2025	03/04/2025