

Strategic Methods for Integrating Building Science and Design

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Keywords: Integration, Pedagogy, Building Science and Design.

The design studio has often been considered central to architecture education, while the building science courses are the backbone of architecture. While NAAB accredited programs require a body of structures and buildings science courses, the integration of these courses into design studios has been implemented to varying degrees across NAAB accredited institutions. Some programs tackle this integration through a comprehensive design studio in the upper-class years, while others advocate for this integration at the 1st-year design studio. The debate surrounding integration between building science courses and design studio continues with some questioning how much integration is necessary in the early design studio, while others seeing it as essential to the design studio and pushing for a direct link. This paper aims to add to the conversation by relaying our experiences in proposing a pedagogical symbiotic relationship between the building science courses and the 3rd-year design studios at our university.

This paper questions how can we envision building science and studio courses as a Yin and Yang relationship where one can't exist without the other? How can the integration lead to more successful understanding of concepts taught in building science courses? How can the work being done in design studio be used as a teaching tool in the building science courses and vice versa? What are the best practices for achieving this integration?

Integration as a teaching tool was tested during the students' 3rd-year. Subject matter from Environmental Systems and Structures courses were used in the development of discrete exercises to convey specific concepts instead of challenging the students with a complete integration as would occur in a later comprehensive design studio or thesis. The paper presents lessons learned, surveys conducted before and after the exercises and conclusions from the authors on how to improve on this pedagogical approach.

INTRODUCTION

Architecture as a profession is defined as built form that encompasses both art and science. Integration as pedagogy is essential since both design and building science involve questioning, critical thinking, experimentation, and creative

problem-solving. It is also crucial for students to be exposed to the process of integration as an element of design practice.

This paper is the result of dialogue between the 3rd-year design professor and building science professor who shared the same 3rd-year students. The collaborating professors (referred to as CP in the paper) were teaching in traditional "silo" conditions and wanted to have a creative way to ignite the cognitive potential of their students.

The curriculum of the 5-year NAAB accredited undergraduate course has the 3rd-year students taking core courses such as Structures, Environmental Systems, and Design Studios. The comprehensive studio is envisioned in the later years of the program. These 3rd-year students take two Environmental Systems courses, which include subjects such as thermal comfort, plumbing, life safety, acoustics, lighting, passive and active designs, transportation systems, electrical systems, and heat loss and gain as factors in environmental design. The students also take two Structures courses, which include the study of force composition, effect, resolution, equilibrium, and the strength, mechanical and elastic properties of materials. The courses also cover elementary analysis and design of structural framing members in wood, steel, and concrete. For clarity, the CPs have combined Environmental Systems and Structures under the term building science in this paper.

While the students were exploring these structural and environmental concepts, they were focusing on a range of design issues in their studios. In the Fall, the 3rd-year Design Studio focused on phenomenology and an exploration of perception in architecture and how these concepts manifest into built form while negotiating between issues of context and program. The studio investigated the impact of function, structure, site conditions, and the environment on the architectural form while designing a civic space. The Spring 3rd-year housing Design Studio focused on investigating what it means to dwell while developing spaces for domestic life at various scales.

The CP's aim was to maintain these design pedagogical goals while integrating building science subject matter through discrete exercises. Similarly, design studio work was used in building science courses as concepts were being taught to aid in the understanding of the material. These exercises were tested over several semesters and the following sections present lessons learned, surveys conducted before and after the

exercises and conclusions from the authors on how to improve on this pedagogical approach.

LITERATURE REVIEW

A review of the literature reveals that the concept of integrating subjects is not new and has been studied by numerous academics. For example, Claudia Cornett states that integration is about “combining diverse elements into harmonious wholes with synergistic result.”¹ In addition, Astrid Steele and Elizabeth L. Ashworth start their paper with a quote by teacher candidates declaring that “Integration not only brings subjects together but people as well.”²

Despite these benefits, integration between design and building science does not often happen because educators do not understand the process and rely on traditional “silo” approaches to subjects because it is reliable for assessments. The curriculum and teaching demands of the building science and design courses for accreditation boards do not require integration at mid-level. There is no incentive for professors to do integration when the traditional lecture and design courses work to create a graduating student.

Steele and Ashworth provide a framework for integration, summarizing three essential elements for an integrated project: 1) Dedicated Faculty, 2) Subject Connections, and 3) Supportive Administration.³ The CPs embraced these elements as they were developing and testing their approach.

1. Dedicated Faculty - The faculty must spend considerably more time, have a flexible lens and collegiality to do a successful integrated project. The CPs for design and building science have spent time syncing their syllabus to coordinate the various integration exercises.

2. Subject Connections - Integration can only be successful when we combine the two content areas (design and building science) in strategic points of learning to make a useful teaching tool. The paper discusses these points of connections, which depend on existing student knowledge. The student must have basic content knowledge in both subjects before any integration is possible. The CPs have coordinated their syllabus and assessment connections so students can have one final product for both courses.

3. Supportive Administration - The department encourages this creative, collaborative dialogue to enrich student learning.

As the CPs embarked on thinking about best practices for integration, a study of other programs was conducted. For example, the education system at Middle East Technical University (METU) Ankara, Turkey, has a four-year, eight-semester program. At this institution, the building science courses are taught in a traditional “silo” lecture format. Starting in 2nd-year, structures is taught in four required courses, teaching statics,

the strength of material, reinforced concrete system, and steel and cable design. In addition, they also have a 3rd-year design studio that focuses on a short-term design project on structural design. The authors observed that students showed discontent with the functioning of lecture courses, and even when students emphasize structures in design, such work is rarely appreciated or scored high. The academic staff also assessed a lower motivation among the students to synthesize the lectures to studio and design work. However, eventually the METU changed their teaching approach to embrace integration.⁴

The study of the curriculum at the NAAB accredited program at Pratt University, New York, reveals that in the 5-year program students engage in structures and building science courses along with the design studio from the 2nd year.⁵ The integration is done with a comprehensive studio. This type of integration has drawbacks as typically several outside consultants influence the design with the teaching faculties losing control of assessment objectives.

METHODOLOGY

Based on this literature review, this paper aims to tackle best practices for integrating building sciences and design studio to lead to a more successful understanding of concepts taught in the building sciences courses and new teaching tools for reinforcing these concepts in the design studio.

Integration here refers to the reinforcing of discrete concepts from building sciences courses in the design studio and demonstrating to students how they could aid, order, and inform the design. The use of design studio work in small exercises within the building sciences courses also helps as a teaching tool to further the understanding and application of key concepts in those courses. The aim of the repetition of exercises is that concepts are being reinforced, applied, and retained by students. In addition, students understand their role as a professional who integrates structural engineers, and other consultants work in their designs. These exercises also teach students how these parameters can inform their design in an iterative process.

This method of integration was tested over several semesters during the students’ third year of the program. The exercises were given in Spring 2018, Spring 2019, and Fall 2019. The scale of the design studio projects and discrete exercises allowed for testing both environmental systems concepts and structural integration. The smaller scale allowed the students to apply their knowledge of specific concepts and provided points of assessment for the CPs. Each semester in question, a specific exercise was chosen based on the design program, design studio pedagogy, the feasibility of integration within a selected time frame, and in consideration with the course content being covered in building sciences classes. This ensured that the reinforcement of building science content aligned with design studio goals and course objectives. The ability of the content material to play a pivotal role in informing the design studio

project was also a factor in crafting the integration exercises. These exercises were as follows:

SPRING 2018 EXERCISES

1. Selecting a Structural System and Materials Exercise.

This integration exercise was during a short 5-week Accessory Dwelling Unit (ADU) design project. Reasons for selecting a structural system and characteristics of various structural systems were taught in structures classes and an exercise was given for selecting a structural system for their design studio project.

2. Passive Strategies Exercise.

In this integration exercise, the ADU project was used in the Environmental Systems course and became an effective tool for teaching sustainable strategies. The scale of this project was small enough that multiple strategies could be explored, and students could grasp how these sustainable strategies could inform the design.

SPRING 2019 EXERCISE

1. Life Safety and Egress Exercise. This integration exercise was implemented during the design of a small 14-unit multi-family building with ground-floor retail. The studio had a community engagement arm (working with a member of the community as a client), and therefore it was deemed appropriate to use this project for students to confront the realities of designing egress in a multi-family dwelling. Students were given a life safety exercise in their Environmental Systems class using the multi-family design studio project. They were asked to calculate occupancy and develop drawings outlining egress paths, distance, exits, sprinklers, and alarms. The components of the egress system were reinforced during the studio as the design developed.

FALL 2019 EXERCISES

1. Selecting a Structural System and Materials Exercise.

This integration exercise was implemented during the design of a Community Museum. The CPs developed a similar exercise that was given in both the Structures course and Design Studio to assist students in selecting a structural system and materials. Students explored the reasons why a particular system and material would be chosen based on their design intent.

2. Sustainable Strategies Exercise.

The students were asked to integrate sustainable strategies in their studio projects. They had to incorporate one of the following: LEED, WELL building, Living Building Challenge, Passive House and Net Zero strategies into their design.

These exercises were given at specific points in the semester after coordination between the CPs. The analysis of successes and failures of these connection points and the overall integration exercises was a crucial aspect of the process. The students were assessed and given surveys to capture their experiences in this endeavor.

For this research, upper-class students who completed the 3rd-year studio and building science sequence were given surveys about their experiences during the integration exercises. Students were asked to rate their perceived building science knowledge as well as whether they saw any improvement in their understanding of both structures and building systems after the completion of the integration exercise. They were also asked the degree to which they were able to apply the structural or building systems concepts to their design studio project. These questions used a rating scale of 1-5 where 1 is poor, and 5 is excellent.

Current 3rd-year students were given a variation of the survey as a baseline to be compared against after completion of the 3rd-year sequence. These students were also asked about their perceived knowledge of structures and building systems. To gain insight into their views on the importance of integration, these students were asked whether integration is vital to the studio design process. Furthermore, the CPs asked if their 2nd-year studio project could have benefitted from such an integration.

In addition to these scaled questions, all students provided written feedback regarding their thoughts on integration strategies that they thought could be beneficial. In addition, the CPs assessed the studio work to determine if learning outcomes of the exercises were achieved. The results from these surveys and assessments are described in the following section.

RESULTS

The results from the student questionnaires were analyzed, focusing on the rating scale as a way to quantify the students' experiences. In the evaluation of the findings outlined below, we equated a 3 in the 1-5 rating scale as average. Ratings of a 1 and 2 are considered below average and those of 4 and 5 above average in the evaluation of the student responses.

The survey generated responses from 18 upper-class students and 14 current 3rd-year students. The current 3rd-year students' responses will be used as a baseline for evaluation at the end of the 3rd-year sequence. The survey asked 1) On a scale of 1-5, how do you perceive your structural knowledge (1=poor; 5=Excellent), and 2) On a scale of 1-5, how important is the integration of structures in your current design studio project (1=not important; 5=important)? They were asked similar questions about building systems. Most students ranked their perceived structural and building systems knowledge as



Figure 1. Shaw Community Museum., Fall 2019. Work by Ebubechukwu Joshua Ajayi



Figure 2. Shaw Community Museum., Fall 2019. Work by Jenna Greer

a 2, with 43% for structures and 36% for building systems (see Figure 5a and 5b).

However, when comparing these results to their ratings on the importance of the integration of building sciences, it is clear that most students believe that integration is essential. Regarding the integration of structures, 12 students ranked this as 3 and higher on a scale of importance. In fact, 57% of the students classified this as 4 and 5 in importance (see Figure 3a). Students were also asked if they thought their 2nd-year design project could have benefitted from thinking about the integration of structures with 64% of students saying yes.

Similar results were found in questions surrounding building systems integration with 9 students saying the integration of building systems in their current design studio project was important at a scale of 3 and higher (see Figure 3b). In terms of their 2nd-year design studio project, 71% of the students agreed that it could have benefitted from thinking about building systems. This supports our research that integration is useful as a teaching tool in building science courses and design studio.

Upper-class students agreed with this, with many stating that they see integration as beneficial to the reinforcing of building science concepts. For example, one student stated that “having a side by side learning experience helps to ensure that there is actual digestion of information.” Another reinforced this point saying, “It is more beneficial to implement structures in design while we are taking the class so that at the end of the semester there is a culmination of knowledge and production.”

FALL 2019 RESULTS

During the Fall 2019 studio, students were introduced to the integration exercises at an earlier stage during the design process compared to previous studios. For example, for the student’s work in Figure 1, structural integration was introduced after initial concept design. This triggered the student to embrace structure as a celebratory element in his design rather than an afterthought. This is evident in the final execution of the project. Because integration happened earlier in the design process both CPs were able to assess the success of integration and the effect on the design solution.

Similarly, meeting LEED certification was an exercise integrated and introduced at an earlier stage in the project. The student’s work depicted in Figure 2, embraced specific strategies that informed and strengthened the final design. For example, the student was able to apply the LEED points for daylighting by maximizing daylighting in the space using storefront windows, a curtain wall, and a skylight. The student was aware of solar gains and thought about the performance of the glazing in her design.

These projects exemplify how the student learning outcomes set out in the design studio and building science courses

where met by students. This included an understanding of the influence of building science concepts on the designed solution.

SPRING 2018 AND 2019 RESULTS

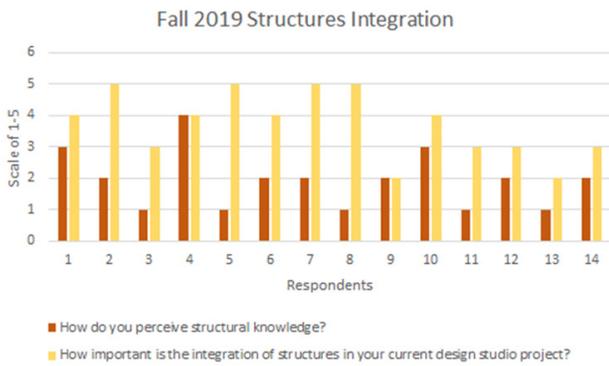
In terms of the upper-class students, the questionnaire revealed mixed results in the students’ perceived improvement in their knowledge of the building science concepts. While we did see some improvement in understanding of building systems and structures concepts, students still generally perceived their knowledge of building sciences as average. Of the 18 upper-class students, 10 rated their perceived structural knowledge as above average (55% of the students). This was on par with those students who rated their structural knowledge as below average (8 students). While most of the students surveyed evaluated their perceived knowledge as above average, this is an area of improvement for retention and reinforcement of information (see Figure 3c and 3d).

In terms of the relevance of the integration exercises in improving their structural knowledge, we once again saw the majority of students (8) rating this as average with four above average (rating of 4). This equates to a percentage of 66.7% rating the usefulness of the integration exercises as 3 or higher. As most students rated this as average, there is room for increasing these numbers during future integration exercises.

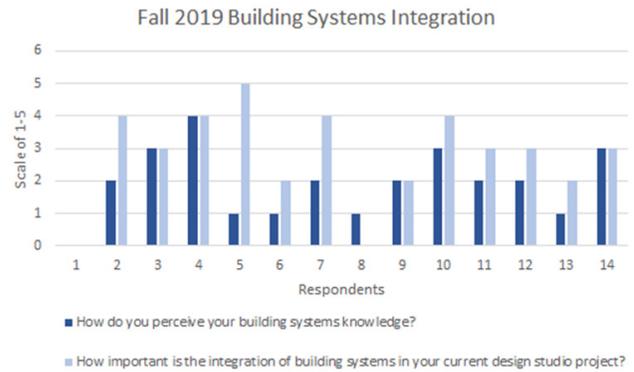
Better results were seen in the building systems integration exercises, where 11 students perceived their knowledge as average to above average (3-5 rating). Responses to the improvement of their knowledge of building systems in design after the integration exercise also established that students saw an increase in this knowledge with 13 students indicating they saw average to above average improvement (3-5 rating). These results are highlighted in Figure 3e and 3f.

In addition to these general questions, the survey asked students to evaluate exercises individually in order to gain an understanding of the degree of success of discrete assignments. These survey results were compared with the student work submitted to see where lapses in knowledge occurred.

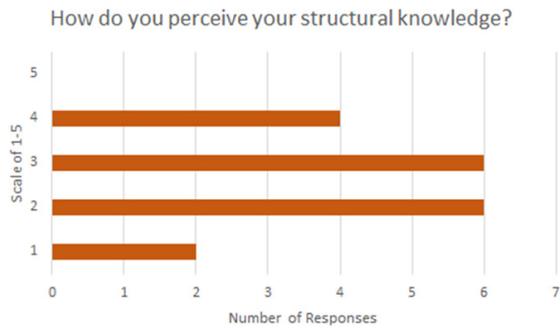
For example, the Accessory Dwelling Unit assignment (Spring 2018), had two separate exercises dealing with structures and environmental systems. The first ADU exercise asked students to select a structural system for their ADU. The student questionnaire reveals 45% of students rated this a 3 in terms of improving their understanding of knowledge of integration of structures in design with 22% rating this at 4. 33% of students still rated this a 1 or 2 combined. The CPs evaluated these exercises and made adjustments for future iterations (see Fall 2019) for improved student knowledge retention. However, the work submitted by the students did reveal that all students attempted the integration of structure, with some having positive results. For example, the ADU project depicted in Figure 4 integrated glulam engineered wood as a structural system.



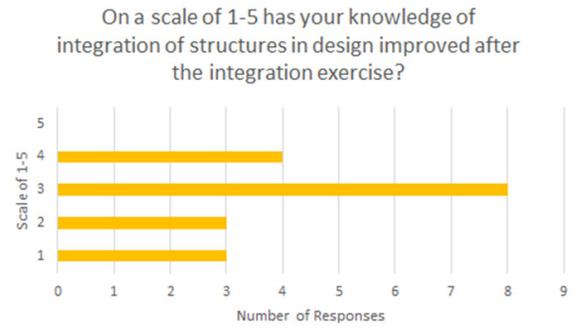
3a. Fall 2019 Structures Integration Survey Results



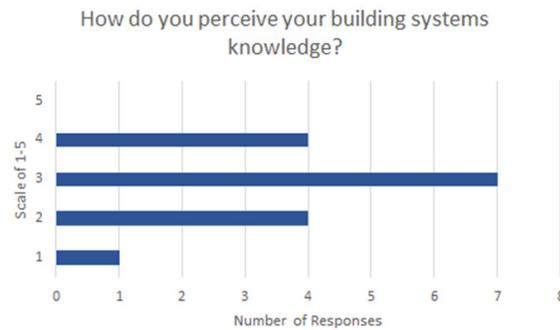
3b. Fall 2019 Building Systems Integration Results



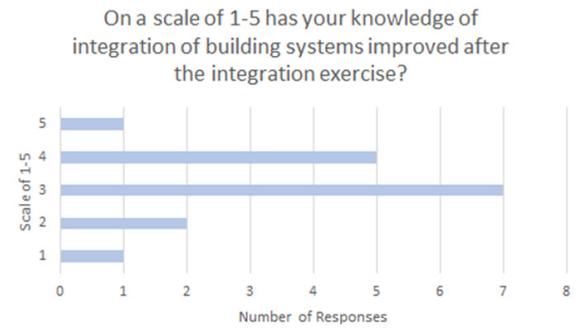
3c. Upper-Class Student Responses to Their Perceived Structural Knowledge



3d. Upper-Class Student Responses to the Improvement of Their Knowledge of Structures in Design after the Integration Exercise



3e. Upper-Class Student Responses to Their Perceived Building Systems Knowledge



3f. Upper-Class Student Responses to the Improvement of Their Knowledge of Building Systems in Design after the Integration Exercise

Figure 3. Summary of Survey Results.

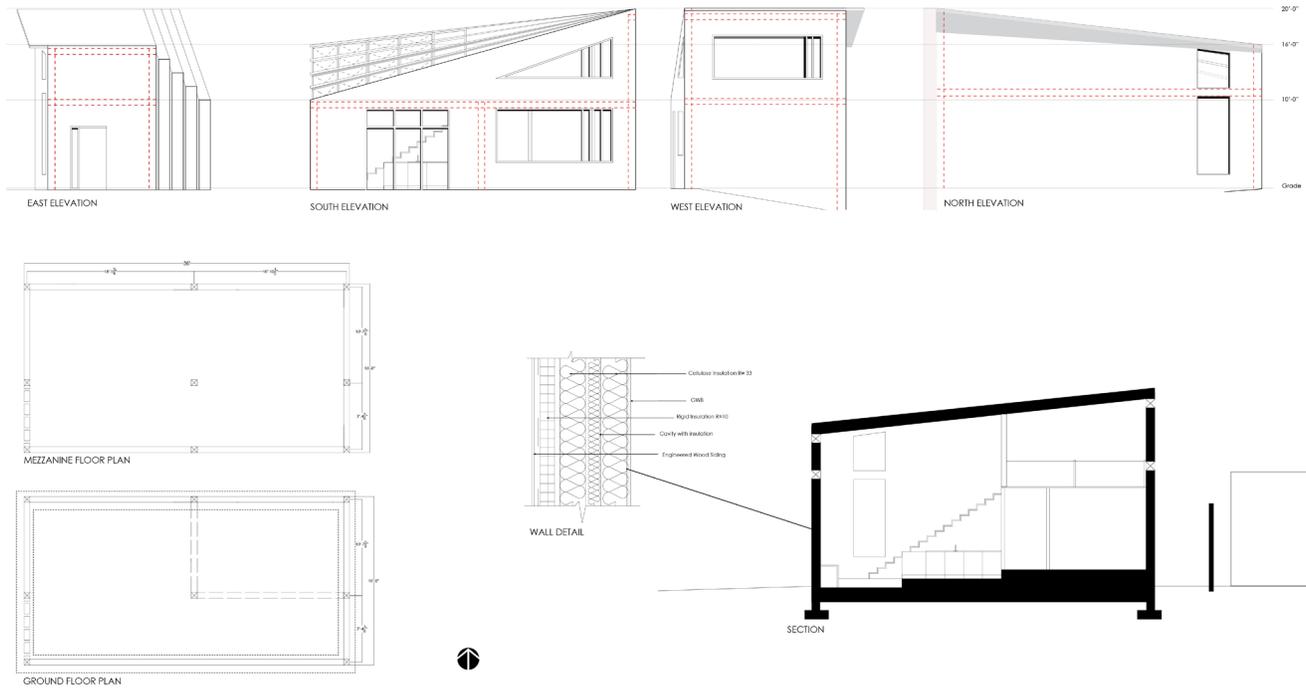


Figure 4. Accessory Dwelling Unit, Spring 2018. Work by Oseah Niles.

The ADU design project was used in the structures class to introduce concepts of selecting a structural system and how it could inform their design work. However, while students were able to select a structural system as part of the exercise, it did not inform their development of the design. This was due to a late integration connection point which resulted in insufficient time for further development in the design studio due to the short timeframe of this project. While the building science professor was able to successfully use this project as a teaching tool, the design professor was not able to thoroughly assess the success of the integration of structures in the design course. This integration point was shifted in the Fall 2019 studio to greater success as outlined above.

The second ADU exercise challenged students to think of this small dwelling unit sustainably. Similar results were seen with 34% of the students rating this a 3 in terms of improving their knowledge of integration of passive design strategies. In addition, 33% rated this improvement of knowledge as 4. Once again, 33% rated this as below average with improvement necessary here as well. The work produced by many students showed that they were able to grasp the key concepts. The scale of this project ensured that students were able to wrap their heads around the many potential passive strategies that could inform the design of the building. The assessment by the building science faculty found that almost all the students understood the concept of passive design better with this application, and it reinforced vital concepts from the class.

This exercise had an earlier connection point and students were able to analyze how sustainable principles could inform the design. For example, one student explored passive house principles which informed her roof form and ventilation system as well the wall section of her ADU (see Figure 5).

CONCLUSION

The student responses and assessments show that integration is essential in architecture pedagogy. The results emphasize that reinforcement of concepts across exercises and courses had positive knowledge retention for the students. However, the results show a need for improvement. The CPs established that reinforcement could be improved by introducing multiple exercises in the same year. The students’ retention of information could only be achieved by further repetition in subsequent years. For example, during one of the students’ written responses, a student stated, “If you want us to know it by 4th year, expose it to us in 2nd year. It takes a lot of time to sink in, so repetition can help.” This is a sentiment expressed by many students who advocate a potential shift in the timeline of structures integration to promote earlier delivery of concepts for improved retention. There is evidence in the literature study where other institutions start building science courses in 2nd year and continue to the upper-class years.

The CPs found that the timing of the point of subject connection could be improved to achieve better integration. For example, a shift in the connection point across the courses to ensure earlier integration of selecting the structural system exercise during

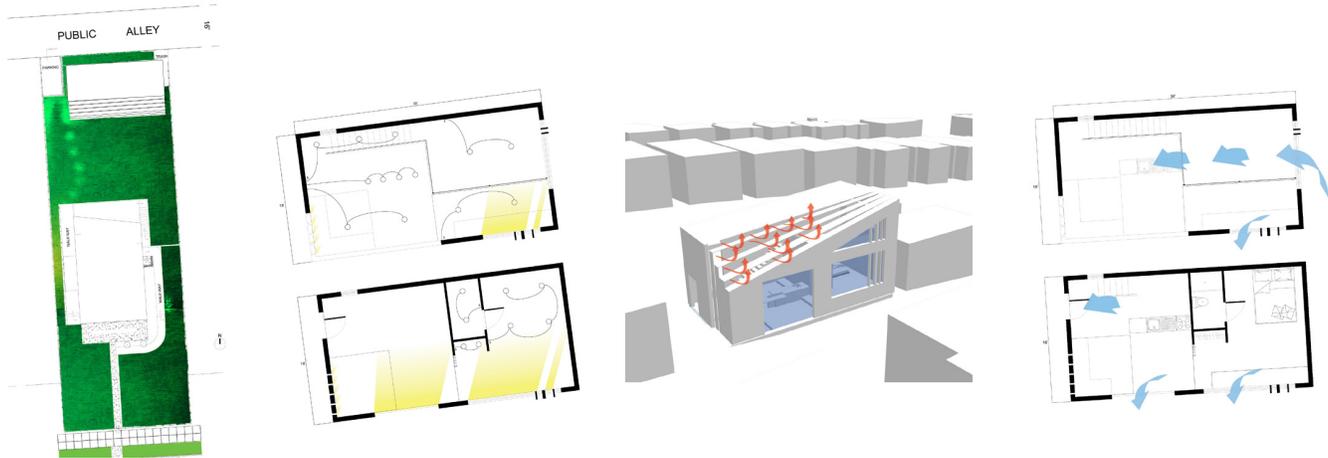


Figure 5. Accessory Dwelling Unit, Spring 2018. Work by Oseah Niles.

the preliminary design phase of the design studio. This ensures that the students had the flexibility to absorb building sciences into their design rather than an afterthought.

The systematic integration of smaller exercises also helped in creating balance in both course exercises, which were combined, and the assessment of student work was done equitably. The scale of projects being smaller for integration helped the depth of learning. In addition, the intention of giving the students a taste of integration in practice was achieved.

This paper opens avenues for future research in how the creative mind thinks and potential techniques and technologies to challenge students to make cohesive design solutions. Further research aims to explore and understand how the creative brain of a student processes the factual learning of building science. A study of how the creative brain processes and retains information could lead to integration exercises which capitalize on the design student as a visual learner. For example, incorporating more structural models, 3D and computer simulations, to use as a tool for integration and assessment. The CPs aim to explore further pedagogical strategies for design and building science integration to make the learning process holistic and equitable to all.

ENDNOTES

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