# Board 323: Integrating Servingness in a Mini-Capstone Project: Resilient and Sustainable Emergency Housing Design

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# Integrating Servingness in a Mini-Capstone Project: Resilient and Sustainable Emergency Housing Design

Emergency housing has become a necessity in Puerto Rico due to the size and frequency of extreme natural events such as earthquakes and hurricanes that affect the island. The Resilient Infrastructure and Sustainability Education – Undergraduate Program (RISE-UP), funded by National Science Foundation (NSF) has developed an interdisciplinary curricular sequence to educate students to design infrastructure to withstand the impact of natural disasters. Three campuses of our university system collaborate in this interdisciplinary effort. Participating students, pursuing undergraduate degrees in engineering, architecture, and surveying, take courses together and participate in co-curricular activities (both online and in person through field visits). RISE-UP integrates servingness as a tool that contributes to the formation of students' sensibility to social dynamics connected to the educational experiences. The final course of the curricular sequence was designed to integrate servingness by addressing a community need during and after a natural disaster. During the final course, students apply the knowledge gained in the program to provide a solution to a design problem. The spring 2021 semester exercise was the design of a set of emergency houses based on a repeated unit. The houses' design requirements include environmental considerations, rainwater management, the use of natural ventilation, electric power autonomy during blackouts and structural stability of the units to face both seismic and wind loads. This paper discusses the semester project and presents the design solutions of the interdisciplinary groups of students who took part in the course. It also discusses the results of a survey whose goal was to explore the perception of the students about their achievements when taking part in the course and the dynamics seen in the course.

**Keywords:** Interdisciplinarity, RISE-UP, Capstone, Design Project

## 1. Introduction.

Academic learning settings have often failed on providing students with scenarios that resemble future experiences that they will face in their professional life. In fields related to infrastructural design, rarely are designers and engineers involved in academic multidisciplinary scenarios.
To address this important void, we have developed the Resilient Infrastructure and Sustainability Education Undergraduate Program (RISE-UP), a collaborative academic and research project funded by the Hispanic Serving Institution (HSI) program of the National Science Foundation (NSF). RISE-UP is a program that developed an interdisciplinary curricular sequence that is focused on the development of skill that future architecture and engineering professionals need to design resilient and sustainable infrastructure [1] This paper describes the semester-long project that was assigned in the "Design-Build" course, which is the last course of the curricular sequence. Through this course, students were asked to develop an interdisciplinary design project. The course follows the academic model of integrated project delivery [2], where teams of students were asked to design a project based on the development of an emergency housing complex. The project consisted of designing a set of four emergency dwellings. The project derived the purpose of being a mini capstone [3] where interdisciplinary groups of students were able to use all the tools acquired in their undergraduate programs. Simultaneously, students can contribute to one of the goals of society through research and development of emergency housing in Puerto Rico [4] The paper presents the instructional design, results, and evaluation of the Design-Build course, and finally reflects about lessons learned and relevance of this type of interdisciplinary learning scenario.

## 2. Methods and Results.

### 2.1. Method / Semester Project.

The design project consisted of conceptualizing a group of emergency houses. Four small living units with the same floor plan, interconnected by a central open space where the persons will be able to interact and develop a sense of community. These small units are expected to be self-sustaining energy wise, and they are also designed with self-sustained environmental considerations that include rainwater management, natural ventilation, and stable enough to withstand both seismic movement and strong winds. The design of these units need to take into consideration the possibility of adding more units if necessary, to complement functional requirements of each family. The project requires each team to design a community/unit system of four emergency houses., which will function as base units to house these people temporarily, but which will allow them to combine this group of houses in a stable manner in the future. The project was divided into three phases that are described below.

1. The first phase, analysis, and evidence, contains the content requirements shown in Table I. In this phase, teams present a summary of the analysis and project goals and a an estimate of costs. The expected level of detail, which is the overall state of the design at this point in its design process [5] is LOD 100.

2. The second phase, alternative presentation, requires the student team to perform a problem analysis and come up with a preliminary design and preliminary cost estimate. The expected level of detail is LOD 200.

3. The third phase, final presentation, requires the student team to continue the analysis of the problem and come up with a detailed cost estimate. The expected level of detail is LOD 200.

At the end of the semester, the internal evaluator of the RISE-UP Program administered a questionnaire to assess if students perceived that the learning outcomes were achieved. The dynamics among students and professors was also explored.

### 2.2. Results.

#### 2.2.1.Project.

During the spring 2021 semester, 30 students from the first RISE-UP cohort enrolled in the course. These students were divided into four interdisciplinary teams and included students from the following disciplines: architecture, civil engineering, electrical engineering, and surveying. The location selected for the houses was the sector of Barrio El Ingenio in the municipality of Toa Baja in Puerto Rico. The nucleus to develop must be constituted from a maximum of four houses. Each unit must house between two to four people and have the potential for adding new units. The four original units must be able to function as a Microgrid.

During the project's first phase, the interdisciplinary groups established their work goals, focused on social, structural and energy aspects. Table 1 includes a list of each group goals.

**Table 1. Work goals stated by each of the groups.**

| Group | Established Goals |
|---|---|
| Mini Palmas | • Suitable for people with disabilities<br>• Family-friendly environment<br>• Resistant to earthquakes and hurricanes<br>• Within specified budget<br>• Lifespan between 10 and 30 years<br>• Rainwater harvesting<br>• Resource monitoring<br>• Solar energy micro-grid |
| Manglar | • Off-grid water and electric energy<br>• Professionalism<br>• Innovation<br>• Modularity and expansion<br>• LEED Certification |
| El Batey | • Robust and adaptable design that can withstand extreme environmental events<br>• Water storage system and Microgrid design<br>• Design within the given budget<br>• Design that facilitates a collaborative construction process with residents<br>• Module size: 80 square feet<br>• Community size: 1200 square feet |
| Casas | • Modularity and expansion<br>• Off-grid water and electric energy<br>• Suitable for people with disabilities<br>• Resistant to earthquakes and hurricanes |

Then the teams made a distribution of tasks using the Responsible, Accountable, Consulted, Informed (RACI) matrix a tool that promotes communication and efficient workflow across team members [6] Using the RACI matrix, team members define their personal goals within the project. In this way, expectations can be supported, and processes streamlined from the beginning to the end of the project. Each team performed the required site analysis. The analysis was carried out in an interdisciplinary way, where factors such as soil quality, solar irradiance, flood plain, among other things, were considered. The plots of land selected by the teams to find their housing complex are shown in figure 1. In addition to this, each team managed to make a preliminary analysis of the project's energy system to determine the critical loads that the modules should have.

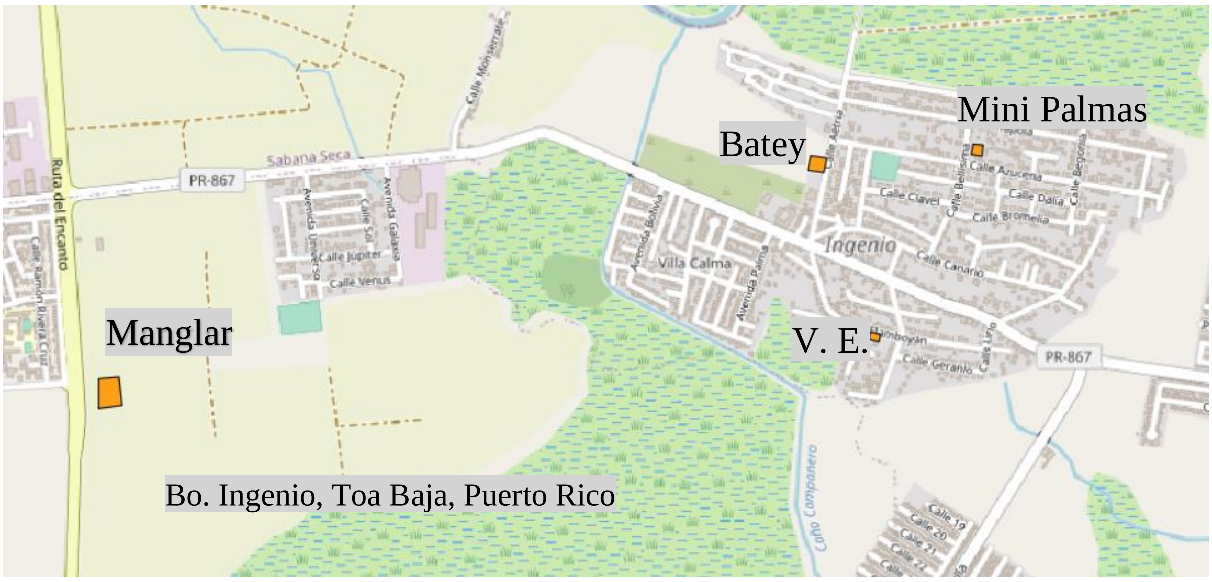


**Figure 1. Site selected per project**

After the first phase, the teams were working on their projects while taking a set of classes on the principles of design-build focused on delivery and acquisition. These classes served as a guide in managing their projects. In addition to this, the professors and teaching assistants served as support to clarify doubts and corroborate that they had the proper criteria when carrying out the different exercises of the project. This clarification of doubts is outside and within the class period.

In phase II the teams presented their development of the proposed proposed solution and the progress of their projects. They managed to deliver the spatial and constructive definition of the housing complex. A partial design of the housing modules was delivered. These partial designs were made up of things like spatial masses, preliminary structural elements, materials to be used in the house, water system logic, ventilation planning, special considerations that should be pending, among many other things.


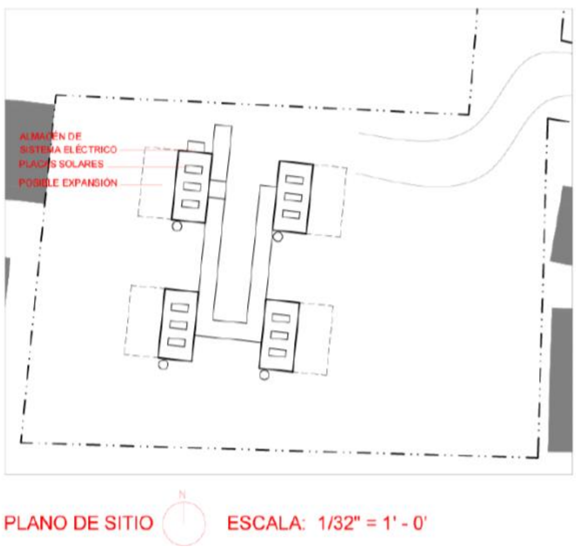

**Figure 2. Space planning and distribution in the site - “Mini Palmas”**

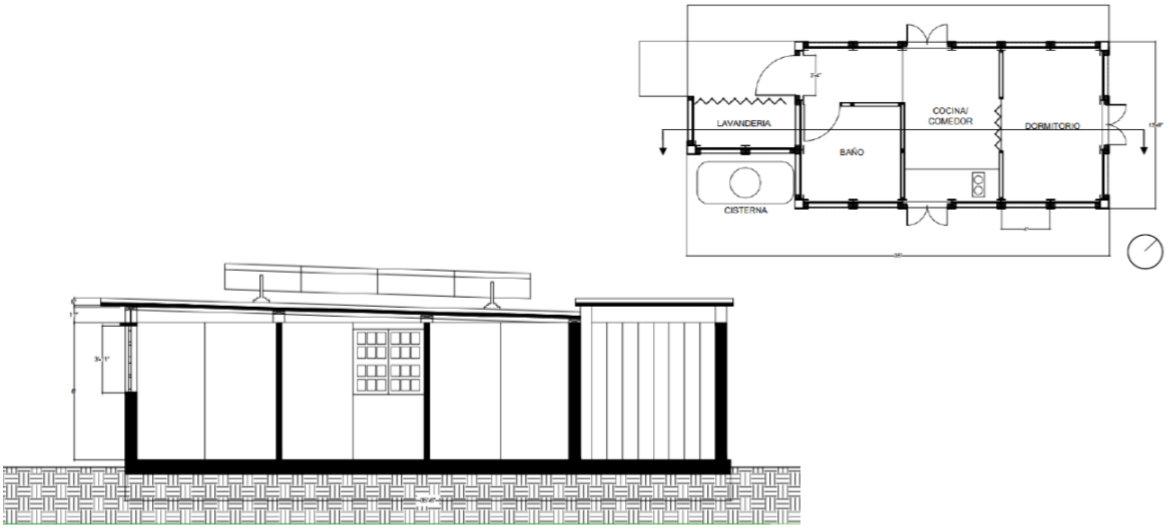


**Figure 3. Space planning and distribution in the site - “Manglar”**

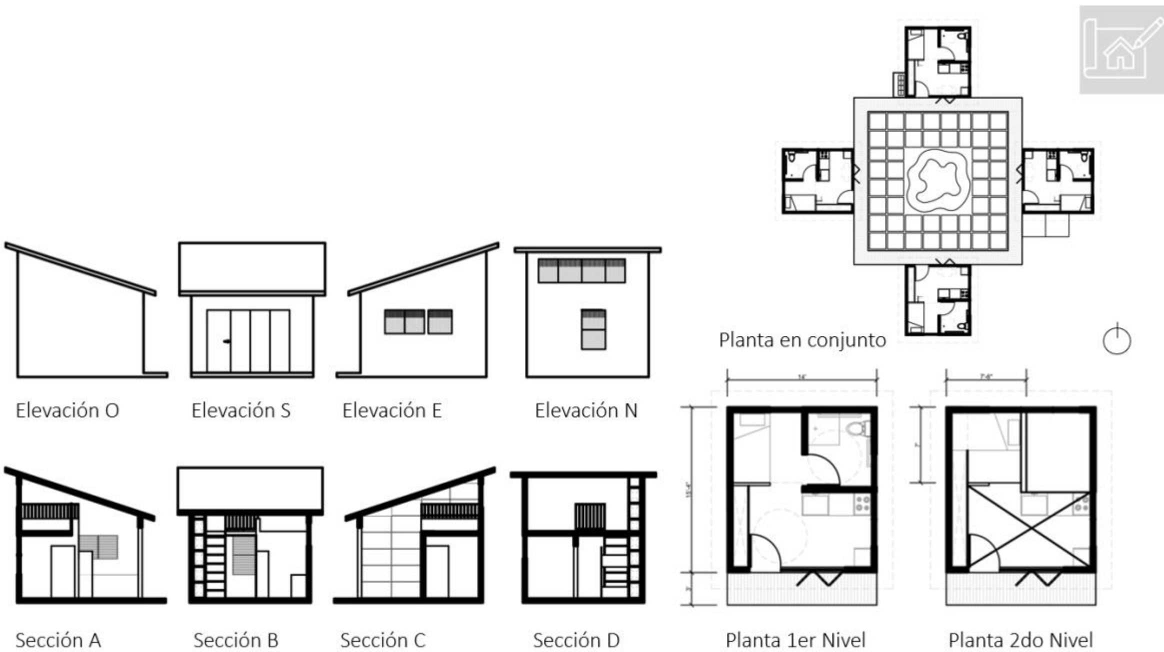


**Figure 4. Space planning, cross-sections and site distribution- - “El Batey”**

**Figure 5. Space planning and site distribution- "Casas"**

Using these partial housing modules designs, the students carried out multiple analyses. Regarding the electrical system, they managed to make an energy analysis of demand vs. estimated production for the different days of the year. In the same way, they defined the equipment to be used for the electric power system. On the structural system, they managed to make a variety of analyses. Some analyzes were carried out according to their resistant qualities and materiality, others involved fabrication methods, and some other were based on simulations. Based on this, students were also able to estimate the cost of the modules.

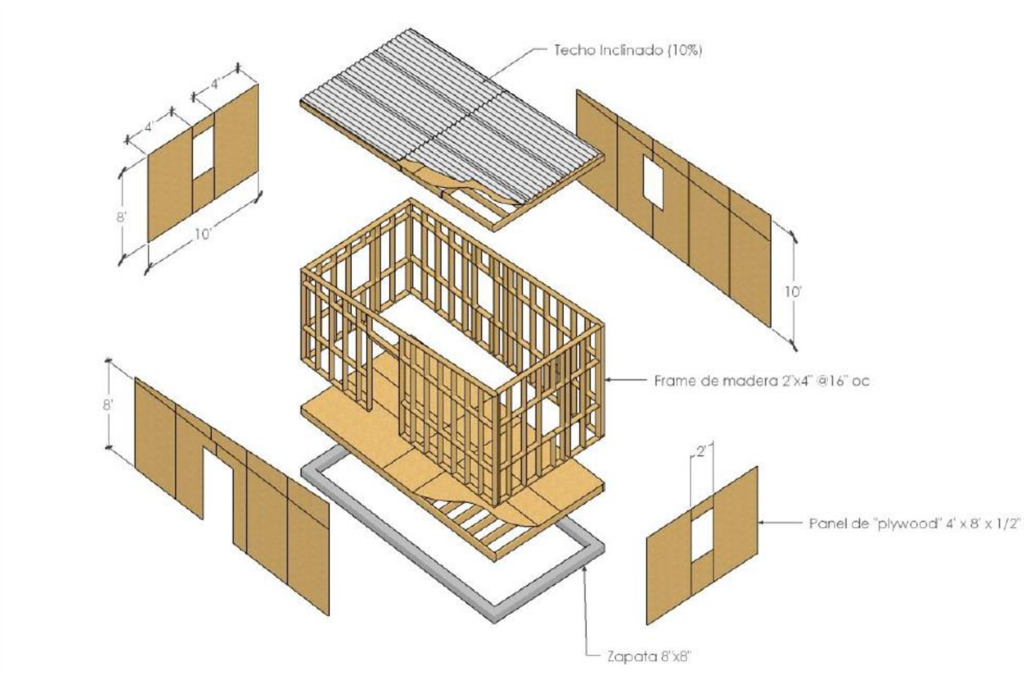

**Figure 6. Construction Assembly - “Mini Palmas”**

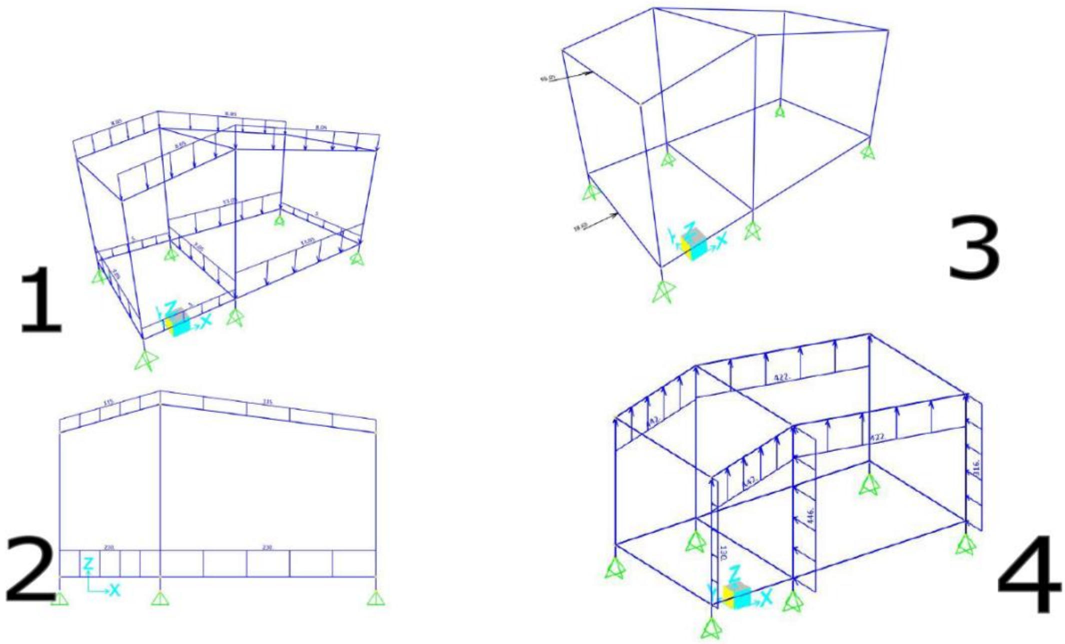


**Figure 7. Seismic model using ETABS – “Casas”**

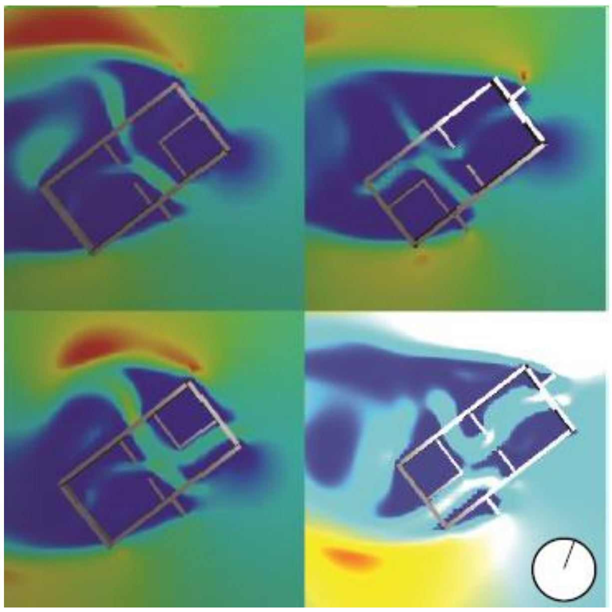

**Figure 8. Ventilation analysis using Autodesk FlowDesign - “Manglar”**

Finally, in phase III, the teams presented their final designs for the housing modules. These designs included architectural plans, facades, structural plans, wind and energy simulations, and cost estimates.

**Figure 9. Final Project Renders - "Mini Palmas"**

**Figure 10. Final Project Renders - "Manglar"**

**Figure 11. Final Project Renders- “El Batey”**

**Figure 12. Final Project Renders- "Casas”**

**2.2.2.Evaluation.**

Students answered a questionnaire to determine how well the expected learning outcomes were achieved. In the questionnaire, a 5-point Likert scale was used, in which the values progressed from 1 = “Not much” to 5 = “A great deal”. The means for each item were then calculated.

The means obtained for each item fluctuated between 4.50 and 4.80 / 5-point scale. All the averages were above 4.40, which shows that the expected outcomes for this course were achieved. This course is considered the capstone course in the RISE-UP curriculum and requires the integration of concepts and skills learned throughout the curricular sequence on resilient and sustainable infrastructure design. The items with the highest scores (4.80) were: 1) Be creative when designing solutions for specific problems, 2) Integrate human factors in the design and processes, and 3) Adopt an interdisciplinary approach to the design and resolution of problems. problems. The results for each item are included in Table 2.

**Table 2. Assessment of learning outcomes.**

| Item | Average |
|---|---|
| Being able to work with students from different disciplines in the project's design. | 4.75 |
| Being able to apply concepts, theories and applications learned in earlier RISE-UP courses. | 4.75 |
| Complete tasks that require assuming a variety of roles, collaboration and coordination with others. | 4.75 |
| Being able to use information from various sources and disciplines to carry out a task. | 4.75 |
| Be creative in designing solutions to specific problems. | 4.80 |
| Integrate human factors in the design processes. | 4.80 |
| Have guarantees of resilience and sustainability in design and construction. | 4.75 |
| Take an interdisciplinary approach to design and problem solving. | 4.80 |
| Carry out simulations to test the design of ventilation, electrical network, energy distribution, resistance of the structure to hurricanes and earthquakes, etc. | 4.50 |
| Being able to conceptualize a construction budget. | 4.65 |

The perceived course dynamics among students and with professors were also assessed with a questionnaire. A 5-point Likert scale was used, in which the values progressed from 1 = "Never" to 5 = "Always". Means for each item were obtained and mean values ranged between 4.32 and 4.68 / 5-point scale. All the values obtained exceeded 4.30, which shows that the dynamics of the course were particularly good and productive, as was the professor-student communication. The students worked satisfactorily as a team and were able to benefit from effective communication. The highest scores were obtained in the following items: 1) Opportunities to receive feedback and guidance from professors, and 2) Receive constructive feedback from professors during the final project. Results are included in Table 3.

**Table 3. Students' assessment of course dynamics.**

| Item | Average |
|---|---|
| Were there opportunities available to receive feedback and guidance from professors? | 4.68 |
| Did the professors answer your questions satisfactorily? | 4.53 |

| | |
|---|---|
| Did all members of your group work together satisfactorily? | 4.42 |
| Did each member of your group take on their assigned task? | 4.58 |
| Was communication between group members effective? | 4.32 |
| Did the members value and respect the opinion of others? | 4.58 |
| Did you receive constructive feedback from the RISE-UP professors during your capstone project? | 4.68 |

## 3. Conclusion.

The Design-Build course was designed to integrate servingness by addressing a community need during and after a natural disaster. The four interdisciplinary groups of students completed their designs successfully. By working in interdisciplinary groups, they learned to work collaboratively, to integrate human factors in the design process, and develop innovative design solutions. Working in interdisciplinary groups resulted in effective communication and collaboration among team members working towards the common goal of designing emergency houses that are resilient, sustainable, and meet the needs of the target population. Based on the student evaluation results, students were satisfied with their projects and value the feedback, guidance, and constructive feedback they receive from their professors.

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## 5. References.

[1] C. López del Puerto, H. Cavallín, J. Perdomo, J. Muñóz, M. Suárez y D. Vázquez, «RISE-UP: Una herramienta educativa interdisciplinaria para la generación de

infraestructura sostenible y resiliente,» *Revista Internacional de Desastres Naturales, Accidentes e Infraestructura Civil,* Vols. 19-20, nº 17, pp. 202-207, 19, 2, 2021.

[2] . American Institute of Architects, Integrated Project Delivery: A Guide, Version 1 ed., vol. 1, The American Institute of Architects, 2007.

[3] The Glossary of Education Reform, "Capstone Project," 3 2016. [Online]. Available: https://www.edglossary.org/capstone-project/. [Accessed 27, 1, 2023].

[4] National Science Foundation, "PAPPG Chapter III," 2018. [Online]. Available: https://nsf.gov/pubs/policydocs/pappg18_1/pappg_3.jsp. [Accessed 27, 1, 2023].

[5] U. S. General Services Administration, "BIM Software Guidelines: Level of Detail," 8 2017. [Online]. Available: https://www.gsa.gov/real-estate/design-and-construction/3d4d-building-information-modeling/bim-software-guidelines/document-guides/level-of-detail. [Accessed 13, 2, 2023].

[6] D. Miranda and R. Watts, "What Is A RACI Chart? How This Project Management Tool Can Boost Your Productivity," 12 2022. [Online]. Available: https://www.forbes.com/advisor/business/raci-chart/. [Accessed 13, 2, 2023].