



## **Design and Assessment of Architecture/ Engineering / Construction (AEC) Curricula for Resilient and Sustainable Infrastructure**

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# **Design and Assessment of Architecture/ Engineering / Construction (AEC) Curricula for Resilient and Sustainable Infrastructure**

## **Abstract**

The devastation caused by recent natural disasters, such as earthquakes, tsunamis, and hurricanes, has increased awareness regarding the importance of providing interdisciplinary solutions to complex infrastructure challenges. In October 2018, the University of Puerto Rico received a Hispanic Serving Institution (HSI) collaborative award from the National Science Foundation (NSF) to develop an integrated curriculum on resilient and sustainable infrastructure. The project titled “Resilient Infrastructure and Sustainability Education – Undergraduate Program (RISE-UP) aims to educate future environmental designers and engineers to design and build a more resilient and sustainable infrastructure for Puerto Rico.

This paper presents the design, initial implementation, and assessment of a curriculum encompassing synergistic interactions among these four domains: integrated project delivery, user-centered design, interdisciplinary problem-solving, and sustainability and resiliency. The project seeks to foster interdisciplinary problem-solving skills involving architects, engineers and construction managers, in order to better prepare them to face and provide solutions to minimize the impact of extreme natural environment events on infrastructure.

The new curriculum stresses on problem-settings, the role that participants have on defining the characteristics of the problems that have to be solved, learning in action, reflecting on the process, and communication between the different stakeholders. This multisite and interdisciplinary program provides students with the necessary support, knowledge, and skills necessary to design and build resilient and sustainable infrastructure. This instructional endeavor consists of four courses designed to reduce gradually the difference between what students are able to accomplish with support structures and what students are able to accomplish on their own. To maximize and enhance the educational experience, the program blends a technology-infused classroom learning with broad co-curricular opportunities such as site visits, undergraduate research, and internships. As students advance in the program, they will be exposed and required to perform increasingly complex tasks.

During the first year of the program, the following outcomes were achieved: 1) implementation of the faculty teamwork process to develop courses and analyze cases from an interdisciplinary perspective, 2) development and approval of an interdisciplinary curriculum on resilient and sustainable infrastructure, 3) development of case studies on situations associated with disaster and interdisciplinary responses, 4) development of a case study database, 5) establishment of an Advisory Board with government agency representatives and faculty, and 6) recruitment and enrollment of 30 students as the first RISE-UP cohort. In summary, the body of knowledge acquired from this project can serve as a model that can be replicated to develop and enhance academic programs at other institutions.

## **Introduction**

The devastation caused by Hurricanes Irma and María in Puerto Rico in 2017 increased awareness regarding the importance of infrastructure related disciplines enabling interdisciplinary solutions to complex infrastructure challenges. Commonly, the academic preparation of scholars on infrastructure-related disciplines takes place in disjunct professional domains, rarely tackling interdisciplinary problem-solving, nor focused on a systematic understanding of research results and lessons learned from previous disaster experiences [1]. In addition, having students from Architecture/ Engineering/ Construction (AEC) fields exposed to common learning experiences fosters their ability to collaborate as professionals and foresee the importance of their contributions as a team [2].

In order to address these challenges, our research team received funding from the National Science Foundation for a project titled "Resilient Infrastructure and Sustainability Education – Undergraduate Program (RISE-UP). The project aims are to: 1) Develop and implement an interdisciplinary curriculum on resilient and sustainable infrastructure; and 2) Carry out research and developing case studies of real scenarios related to infrastructure, starting with the damages caused by the 2017 hurricanes in Puerto Rico.

The curriculum uses Project Based Learning (PBL), an approach that stresses learning through experiences that echo settings similar to the ones in the real world. According to Schön, this setting fosters the opposite kind of learning described in the tradition of the epistemology of technical rationality [3]. PBL stresses on problem-setting, and the role that participants have on defining the characteristics of the problems that has to be solved. This approach to building design situations requires collaboration and interdisciplinary work.

This NSF-funded project encompasses the ensuing broader impacts: 1) To benefit society by increasing infrastructure capacity through in-depth training engineers, surveyors, and environmental designers on resilient infrastructure; 2) To work on issues related to resiliency and sustainability; and 3) To develop an encompassing database of case studies that will be available for research and modeling to other potential users.

## **A Collaborative Multisite and Interdisciplinary Program**

The University of Puerto Rico (UPR) consists of eleven campuses, each offering different academic programs. UPR-Rio Piedras, in the San Juan metropolitan area, houses the School of Architecture; UPR-Mayaguez, in the west part of the island, houses the College of Engineering; and UPR-Ponce, in the south part of the island, offers two-year associate and articulated degrees in Engineering and Construction. Prior to the implementation of this initiative, the Architecture/ Engineering/ Construction (AEC) curriculum had students developing in silos, without the required interaction and learning experience of work with other infrastructure-related disciplines [1]. To implement this initiative, a collaborative platform among the three campuses was created. This allowed faculty from the three campuses to develop an integrated curriculum, offered as a minor degree. It also allowed for students pursuing undergraduate degrees in environmental

design, civil engineering, electrical engineering, and surveying the opportunity of sharing a common curriculum and taking classes together. Because of the geographical location of the three campuses, both collocated and remote interactions take place.

## **Project Approach**

The research design for this project consists of a quasi-experimental approach because it does not provide full control of potential confounding variables [4]. To develop an interdisciplinary program in resilient and sustainable infrastructure, the researchers used a two-prong strategy: development and implementation of an interdisciplinary curriculum and case study research.

## **Results**

During the first fourteen months of the project, the following outcomes were achieved: 1) implementation of the faculty teamwork process to develop courses and analyze cases from an interdisciplinary perspective, 2) development and approval of an interdisciplinary curriculum on resilient and sustainable infrastructure, 3) development of case studies on situations associated with disaster and interdisciplinary responses, 4) development of a case study database, 5) establishment of an Advisory Board with government agency representatives and faculty, and 6) recruitment and enrollment of 30 students as the first RISE-UP cohort. Below we describe specifics of the above-mentioned outcomes.

- 1) Implementation of the faculty teamwork process to develop courses and analyze cases from an interdisciplinary perspective: This was achieved through the collaborative development of the coursework related to RISE-UP. Representatives of the three campuses involved in this proposal worked collaboratively in the development of the content. This interdisciplinary collaboration has led to the advancement of a set of integrated courses in which students are exposed to a holistic approach to environmental evaluation and design.
- 2) Development and approval of an interdisciplinary curriculum on resilient and sustainable infrastructure, Faculty from the three campuses collaborated in the design of four interdisciplinary courses, each with cross-disciplinary goals and objectives. Table 1 presents the four courses created and described in sequential order.

Table 1: RISE-UP Courses

<b>Course Title</b>	<b>Brief Description</b>
Fundamentals of Integrated Practice for Resilient and Sustainable Infrastructure	The course focuses on the implications of natural disasters on the design and construction processes, including the human factors, for solving problems of the design team.
Information Technology for Resilient and Sustainable Infrastructure	The course will introduce the information technologies for civil infrastructure that will be used as tools by designers and builders to collaborate in transdisciplinary teams.
Sustainable and Resilient Design and Construction	This course addresses the application of sustainability and resiliency to engineering design and construction. It provides room for discussion of the engineering and ethical principles needed to support green and resilient design and construction.
Design-Build Project Delivery	The course centers on the design-build project delivery process and includes the analysis of the dynamics of the Design-Build process for the development of resilient and sustainable infrastructure.

- 1) Development of case studies on situations associated with disaster and interdisciplinary responses: Nine preliminary case studies have been developed as tests for the full deployment of case studies research for the remainder of the project.
- 2) Development of a case study database: The conceptual aspects of the database have been laid out and a prototype, currently under testing, has been developed.
- 3) Establishment of an Advisory Board with government agency representatives and faculty: The Board consists of five members, each with a particular expertise. It includes one representative from the following agencies and professional organizations: U.S. Army Corps of Engineers (USACE), American Red Cross, The College of Engineers and Surveyors of Puerto Rico, The College of Architects and Landscape Architects of Puerto Rico and the Federal Emergency Management Agency (FEMA).
- 4) Recruitment and enrollment of thirty students as the first RISE-UP cohort: This first cohort of RISE-UP students is a good example of the interdisciplinary diversity sought throughout our project. The cohort includes thirty participants from each of the three intervening campuses (figure 1). All students enrolled in the first cohort are Hispanic. Out of the 30 students, 20 students (67%) are male. Figure 2 shows the distribution of participants according to their academic program and degree pursued. The first cohort of student successfully completed the first course of the curricular sequence in Fall 2019 and are currently enrolled in the second cohort of the curricular sequence. Passing rate for the first cohort was 100%.

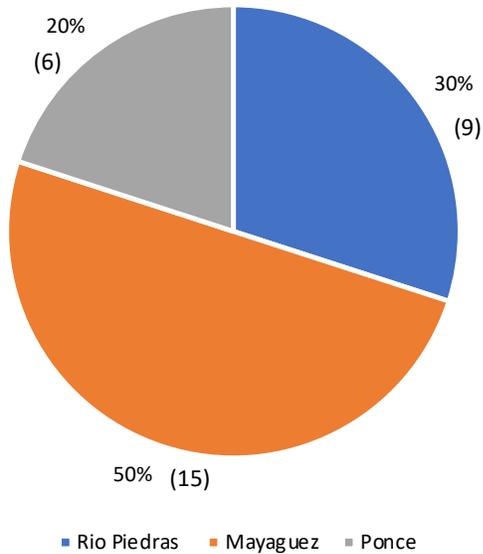


Figure 1. Distribution of students from each campus.

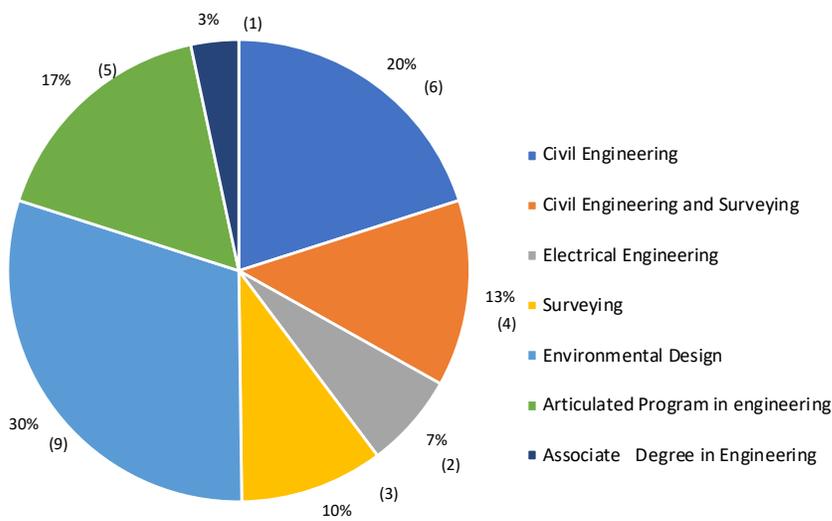


Figure 2. Distribution of participating students according to academic program and degree.

The results of the first-year assessment done by the external evaluator indicate that the project is succeeding at achieving and exceeding its outreach, recruitment and curricular goals. The external evaluator identified the following two areas of opportunity: 1) increase their efforts to improve the gender diversity of the cohorts, 2) include social science approaches to understanding extreme events and disasters into the program’s curriculum.

## **Conclusions**

For the first year, RISE-UP has met its expectations, as it established meaningful multi-campus interdisciplinary collaborations. This paved the way to work towards achieving our two overarching project goals of developing and implementing an interdisciplinary curriculum on resilient and sustainable infrastructure; and carry out research and developing case studies of real scenarios related to infrastructure. At the moment of this writing, the team is selecting the second cohort of RISE-UP participants. To improve gender diversity, particularly in UPR-Ponce, we are collaborating with “Get by STEM”, a project funded by the US Department of Education seeking to increase the number of female students in STEM. Social science has been an integral part of the project that has not been fully implemented yet. Accordingly, the planned curriculum includes guest experts on the subject.

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