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STRUCTURAL RESILIENCE: ADVANCING CIVIL ENGINEERING PRACTICES FOR SUSTAINABLE INFRASTRUCTURE

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Abstract:
Structural resilience is a critical aspect of civil engineering, particularly in the context of sustainable infrastructure development. This abstract explores the concept of structural resilience and its advancement in civil engineering practices to ensure the longevity and sustainability of infrastructure systems. The increasing frequency and severity of natural disasters, along with the challenges posed by aging infrastructure, highlight the need for resilient structural design and engineering practices. Structural resilience goes beyond traditional strength and safety considerations, emphasizing the ability of a structure to withstand and recover from extreme events while maintaining functionality.
Advancements in materials, design methodologies, and construction techniques have enabled civil engineers to enhance the resilience of structures. These advancements include the use of innovative materials such as fiber-reinforced polymers, high-performance concrete, and smart materials that can sense and adapt to changing conditions.
Keywords: *Structural Resilience, Civil Engineering, Sustainable Infrastructure, Advancements, Disaster Resilience.*

1. Introduction

The devastation caused by Hurricanes Irma and María in Puerto Rico in 2017 highlighted the critical need for infrastructure-related disciplines to adopt interdisciplinary approaches in addressing complex challenges. Traditionally, scholars in these fields are trained in siloed professional domains, lacking exposure to interdisciplinary problem-solving and a systematic understanding of research findings and past disaster experiences. This gap underscores the importance of providing students in Architecture, Engineering, and Construction (AEC) fields with shared learning experiences to enhance their collaborative skills and underscore the significance of their contributions within a team dynamic. To tackle these challenges, our research team secured funding from the National Science Foundation for the Resilient Infrastructure and Sustainability Education – Undergraduate Program (RISE-UP). This initiative is designed to achieve two primary goals: first, to develop and implement an interdisciplinary curriculum focusing on resilient and sustainable infrastructure; and second, to conduct research and create case studies based on real-life scenarios, starting with the aftermath of the 2017 hurricanes in Puerto Rico.

The RISE-UP curriculum adopts a Project Based Learning (PBL) approach, emphasizing learning through real-world experiences. This methodology, as advocated by Schön, diverges from traditional technical rationality-

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based learning by emphasizing problem-setting and allowing participants to define the problem characteristics that need to be addressed. Such an approach encourages collaboration and interdisciplinary work, mirroring the professional environment in the AEC fields. This NSF-funded project aims to have several broader impacts. Firstly, it seeks to benefit society by enhancing infrastructure resilience through the comprehensive training of engineers, surveyors, and environmental designers. Secondly, it aims to address issues related to infrastructure resiliency and sustainability. Lastly, the project intends to develop a comprehensive database of case studies, which will be available for research and modeling purposes to benefit other stakeholders and researchers in the field.

2. A Collaborative Multisite and Interdisciplinary Program

The University of Puerto Rico (UPR) is a multi-campus institution offering a wide range of academic programs. Among its campuses, UPR-Rio Piedras is known for its School of Architecture, UPR-Mayaguez houses the College of Engineering, and UPR-Ponce offers degrees in Engineering and Construction. Before a recent initiative, students in these fields often worked independently, lacking the crucial interdisciplinary interactions needed for comprehensive learning. To address this, a collaborative platform was established among the campuses, enabling faculty to create an integrated curriculum. This curriculum, offered as a minor degree, allows students from various disciplines such as environmental design, civil engineering, electrical engineering, and surveying to share classes and projects. This initiative has not only fostered collaboration among students and faculty but has also created a more holistic learning environment. Despite the geographical distance between campuses, both in-person and remote interactions now occur regularly, enhancing the overall educational experience for students pursuing infrastructure-related disciplines at the University of Puerto Rico.

3. Methodology

The research design for this project utilizes a quasi-experimental approach, chosen due to its inability to fully control potential confounding variables. The aim of the research is to develop an interdisciplinary program focused on resilient and sustainable infrastructure. To achieve this goal, the researchers adopted a two-prong strategy. First, they developed an interdisciplinary curriculum that integrates various aspects of resilient and sustainable infrastructure. This curriculum likely draws from diverse fields such as civil engineering, architecture, environmental science, and possibly others, to provide students with a comprehensive understanding of the challenges and solutions related to infrastructure resilience and sustainability. Second, the researchers implemented a case study research component, which likely involves analyzing real-world examples of resilient and sustainable infrastructure projects. By studying these cases, students can gain practical insights into how interdisciplinary approaches can be applied to address complex infrastructure challenges. Overall, this research design allows for a comprehensive exploration of interdisciplinary approaches to resilient and sustainable infrastructure, with a focus on practical implementation and real-world impact.

4. Result & Discussion

During the initial fourteen months of the project, several significant outcomes were achieved. Firstly, a faculty teamwork process was implemented to collaboratively develop courses and analyze cases from an

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interdisciplinary perspective. This approach facilitated the integration of diverse perspectives and expertise, enhancing the content of the coursework related to the project. Secondly, an interdisciplinary curriculum focusing on resilient and sustainable infrastructure was developed and approved. This curriculum, designed by faculty from the three campuses involved in the project, consists of four integrated courses with cross-disciplinary goals and objectives. The courses were created to provide students with a holistic understanding of environmental evaluation and design. Additionally, case studies related to disaster situations and interdisciplinary responses were developed, along with a database to store these case studies. The establishment of an Advisory Board, comprising representatives from government agencies and faculty members, was another key outcome. This board provides guidance and support for the project. Lastly, the recruitment and enrollment of 30 students as the first cohort of the program, known as RISE-UP, was successfully completed. These outcomes mark significant progress in the development of the interdisciplinary program and lay a solid foundation for future advancements in resilient and sustainable infrastructure education. Table 1 presents the four courses created and described in sequential order.

Table 1: RISE-UP Courses

Course Title	Brief Description
Fundamentals of Integrated Practice for Resilient andSustainable 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.

The project has made significant progress across several key areas. Firstly, the development of case studies related to disaster situations and interdisciplinary responses has advanced, with nine preliminary cases serving as tests for the full deployment of case study research in the project's remaining phases. Secondly, a case study database is being established, with conceptual aspects already laid out and a prototype currently undergoing testing. Thirdly, an Advisory Board has been established, comprising five members with expertise from various government agencies and professional organizations, including the U.S. Army Corps of Engineers, the American Red Cross, and others. Fourthly, the recruitment and enrollment of thirty students as the first RISE-

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UP cohort have been completed. This cohort, exemplifying the interdisciplinary diversity sought in the project, consists of Hispanic students, with a majority being male. The first cohort has successfully completed the initial course in Fall 2019 and is now enrolled in the subsequent course, with a 100% passing rate for the first phase. Figures 1 and 2 show the distribution of participants according to their academic program and degree pursued.

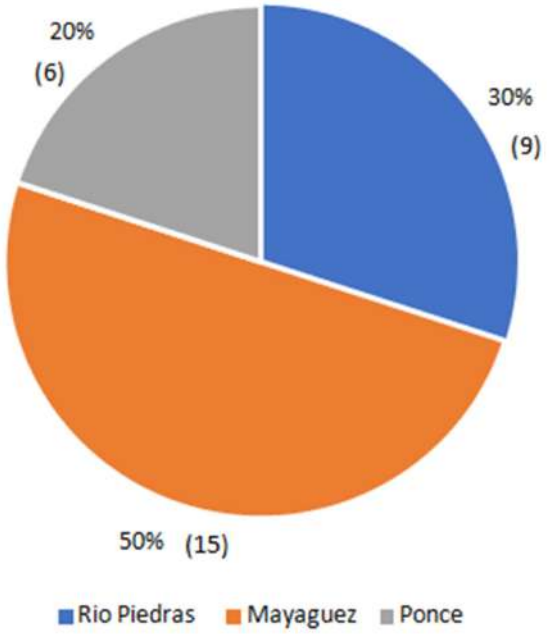

Fig. 1 Distribution of students from each campus.

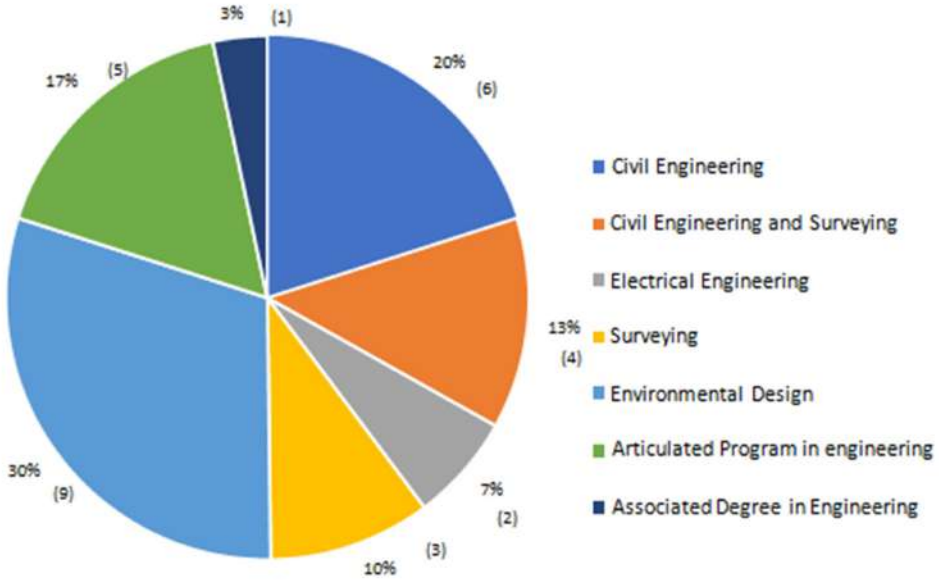

Fig. 2 Distribution of participating students according to academic program and degree.

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The first-year assessment conducted by the external evaluator indicates that the project has been successful in achieving and even exceeding its outreach, recruitment, and curricular goals. However, the evaluator also identified two areas of opportunity for further improvement. Firstly, there is a need to increase efforts to improve the gender diversity of the cohorts, suggesting that the current composition may be skewed towards one gender. Secondly, the evaluator recommended including social science approaches to understanding extreme events and disasters into the program's curriculum. This suggests that while the project is excelling in many areas, there are still areas where refinement and enhancement could lead to even greater success.

5. Conclusion

In its first year, RISE-UP has successfully met its expectations by establishing meaningful multi-campus interdisciplinary collaborations. This achievement has laid a solid foundation for the project to progress towards achieving its two overarching goals. The first goal is to develop and implement an interdisciplinary curriculum focusing on resilient and sustainable infrastructure. The second goal is to conduct research and develop case studies based on real scenarios related to infrastructure. Currently, the team is in the process of selecting the second cohort of RISE-UP participants. To address the need for improved gender diversity, especially at UPR-Ponce, the project is collaborating with "Get by STEM," a project funded by the US Department of Education aimed at increasing the number of female students in STEM fields. While social science has been recognized as an integral part of the project, it has not been fully implemented yet. As part of the planned curriculum, guest experts in social science will be included to enhance the interdisciplinary nature of the program.

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