# Translation of Green Infrastructure for Stormwater Mitigation and Pollution Control Research into Engineering Education

**Meghana Parameswarappa Jayalakshmamma, New Jersey Institute of Technology**

Ms. Meghana Parameswarappa Jayalakshmamma is a Ph.D. candidate in Civil and Environmental Engineering at NJIT with expertise in water quality, water and wastewater treatment, and soil remediation. Her current research focuses on microplastics in stormwater, specifically their fate and transport in the urban Environment. Additionally, Meghana has 2.5 years of industry experience designing wastewater and water treatment plant units, investigating stormwater flooding, and providing turnkey solutions.

**Dr. Ashish D Borgaonkar, New Jersey Institute of Technology**

Dr. Ashish Borgaonkar works as an Assistant Professor of Engineering Education at the New Jersey Institute of Technology's (NJIT) Newark College of Engineering (NCE) located in Newark, New Jersey. He has developed and taught several engineering courses primarily in first-year engineering, civil and environmental engineering, and general engineering. He has won several awards for excellence in instruction; most recently the Saul K. Fenster Award for Innovation in Engineering Education. His research focuses on increasing diversity in STEM education and the STEM workforce. He has received multiple grants to run workforce development training programs as well as undergraduate research experience programs to train underrepresented minority and first-generation students. He is the Founding Director of NJIT's Grand Challenges Scholars Program. He also has worked on several research projects, programs, and initiatives to help students bridge the gap between high school and college as well as to prepare students for the rigors of mathematics. He is also involved in various engineering education initiatives focusing on the integration of novel technologies into the engineering classroom, and excellence in instruction. His additional research interests include water, and wastewater treatment, stormwater management and pollution control, civil engineering infrastructure, and transportation engineering.

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**Abstract:**
Research and coursework are often considered separate parts of the degree programs, due to which research advancements, particularly in non-traditional topics and emerging technologies, take a long time to trickle into the curriculum, engineering education, and workforce development training programs. This disconnect leads to a significant shortage of trained and experienced workforce when a major research breakthrough makes headway into industrial practices. Addressing this, our study advocates integrating such emerging research concepts coupled with active learning strategies, such as special topics or projects, into traditional engineering courses through simple enhancements to the syllabi. This paper outlines three case studies we implemented to integrate the topic of "Green Infrastructure for Stormwater Mitigation and Pollution Control" into undergraduate courses and summer research experiences. This paper discusses how these three activities were designed and implemented. The feedback and performance metrics from these interventions demonstrated the potential of our approach to enrich engineering education and bridge the gap between research and classroom learning.

## 1. Introduction

Engineering education faces the continuous challenge of incorporating the latest research findings into its curriculum to ensure graduates are well-equipped to tackle current and future technological challenges. Traditional methods of curriculum development often struggle to keep pace with the rapid advancement of technology and emerging research areas [1, 2]. Current approaches to integrating research into engineering education primarily involve the introduction of elective courses, predetermined laboratory classes, or the occasional inclusion of term papers from existing courses. However, these methods have limitations, including insufficient coverage of new technologies and the lag in updating course content to reflect the latest research developments. Moreover, a significant gap exists in systematically incorporating emerging research topics into foundational engineering education courses. This gap is partly due to the challenges in aligning academic content with rapidly evolving technological landscapes and the lack of structured approaches to integrate these advancements into the curriculum [3]. As a result, students may graduate with a knowledge base that, while solid in traditional principles, lacks the immediacy and relevance of recent technological progress.

This paper addresses these challenges by proposing a methodical approach to bridge the gap between current research developments and engineering

education. Focusing on integrating green infrastructure for stormwater management and pollution control—a critical area in civil and environmental engineering that responds to the urgent need for sustainable urban development. This study outlines three case studies that exemplify the successful incorporation of this emerging research topic into undergraduate engineering courses and summer research experiences. Our approach leverages active learning strategies and the inclusion of research topics in course projects, assignments, and discussions. By doing so, we aim to proactively intervene in the educational trajectories of undergraduate students by exposing them to contemporary, relevant contaminants and cutting-edge research domains. This initiative is designed to enhance student engagement with current research, foster a deeper understanding of the applications and implications of green infrastructure, and expand their knowledge base. By integrating the latest advancements in engineering research into the curriculum (Figure 1), we prepare students for the workforce and bridge their transition into graduate studies, thereby enhancing their preparedness for industries that are addressing current contaminants with technologies not yet incorporated into existing curricula.

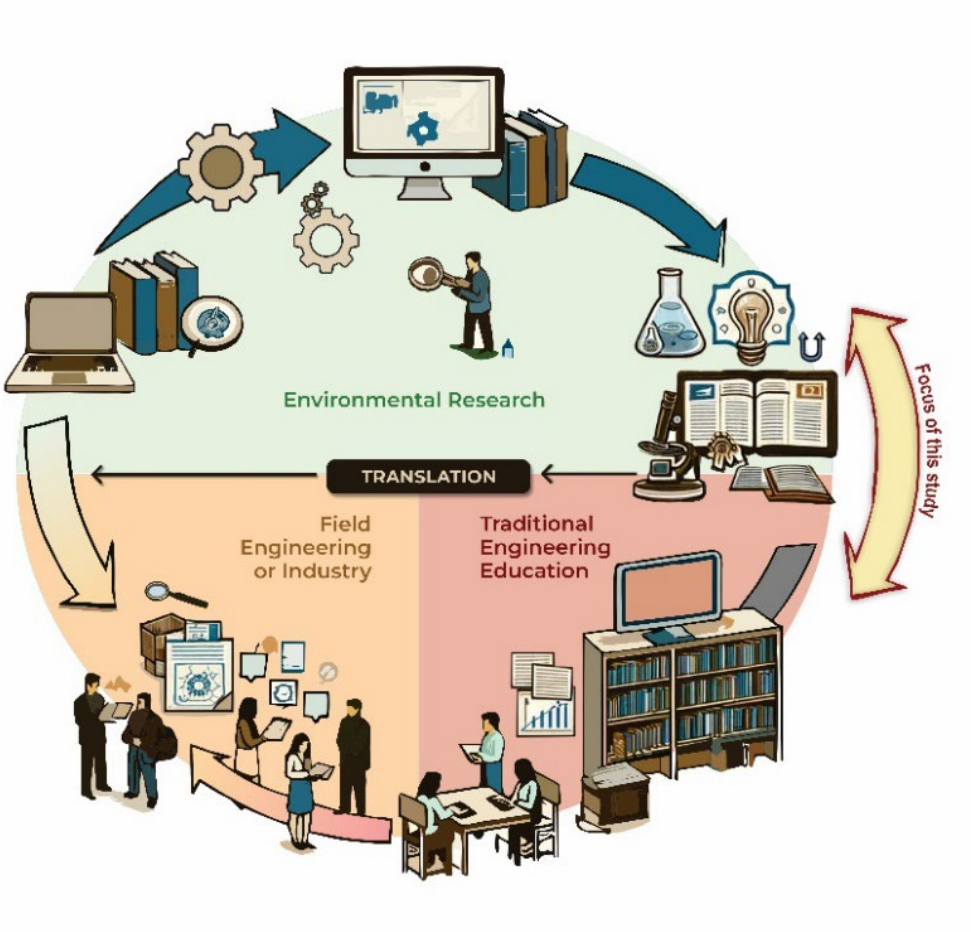


Figure 1: The current gap between Environmental research and Education curriculum.

Furthermore, we discuss the methodology, outcomes, and student feedback from these case studies for replicating the work. These activities can be easily adapted to incorporate other research topics, making them applicable across diverse engineering disciplines. This work is part of a conscious effort by a doctoral candidate to highlight the research translation of her dissertation work into engineering education.

## 2. Research Background

The research considered in this study was "Green Infrastructure for Stormwater Mitigation and Pollution Control". Microplastics in stormwater runoff were the target pollutants, and green infrastructures were investigated to mitigate and control them. Microplastics, one of the emerging contaminants in the environment, are commonly referred to as plastic particles between 1 μm and 5 mm. Microplastic pollution has garnered increasing attention as a global environmental challenge, with its pervasive presence in aquatic ecosystems. Over the past few decades, microplastics in marine and freshwater ecosystems have been extensively studied due to their bioaccumulation in aquatic organisms, either directly [4] or via trophic transfer [5], acting as pollutant carriers [6-9] like heavy metals and hydrocarbons [10], the toxicity of plastic additives [11] and potential exposure to humans via the food chain [12].

Through our experiments, we identified that stormwater runoff, especially from urban areas, acts as a vector to transport land-based microplastics to receiving waters, and their composition varied with different land uses [13]. Green infrastructures are being installed in urban areas as part of stormwater management. Upon investigation, we identified that microplastics are accumulated in rain gardens, potentially from stormwater runoff. Although there are few investigations on microplastics over the years, the lack of standardized methods has led to the variable techniques between the existing studies [13]. This had led to uncertainty in understanding the extent of microplastics issue or implementing effective management strategies to mitigate microplastic pollution. With the current trend, it might take a few more years to develop technologies or strategies to eradicate microplastics from the environment. However, this wait can be shortened with increased participation through engineering education and develop workforce through training students to be ready when a breakthrough technology cuts in the industry.

## 3. Case Studies and Discussions

### 3.1. Integrating into Undergraduate Engineering Technology Course as a Special Topic and Activity (Spring 2023)

The first case study utilized a senior level engineering science course (CET 413-Environmental Science) offered primarily to the engineering technology students. The course already touched upon various environmental science topics such as

hydraulics, hydrology, water pollution and control, and stormwater management among other relevant topics. This course was specifically selected because introducing the topic of green infrastructure for stormwater mitigation and pollution control was a natural extension to the material already being covered in the course. This approach included a coordinated and structured approach where the doctoral candidate was the guest speaker to discuss the current methods and software used to manage stormwater, green infrastructures, and microplastics. Students were then asked to participate in a group exercise with the following prompts –

***Stormwater Mitigation Group Exercise Instructions:***

Pick a topic from the list below and discuss within your group how a Green Infrastructure based solution would fit into this topic. Upload a summary of your discussion to the appropriate submission portal.

List of Topics to be Used for the Group Activity:

1. Safety Analysis of a Stormwater Management Basin
2. Watershed Management Plan
3. Low-Impact Development Design Project
4. Invitation Letter to Stakeholders
5. Task List for a Regional Stormwater Management Planning Committee
6. Stream Corridor Protection Plan
7. Educational Campaign for a Stormwater Management Plan
8. Cost-Benefit Analysis to Compare Stormwater Management Strategies

The feedback from students on the guest lecture (Table 1) was overwhelmingly positive (n=13/13). Many students expressed their admiration for the intelligence and knowledge, highlighting the ability to deliver detailed and interesting information about stormwater management. The students appreciated the real-life applications of stormwater management showcased and found the content about designing green infrastructure and different types of GIs particularly engaging. Furthermore, the summaries uploaded by the students had more real-world practical applications as compared to the theoretical concepts we typically receive. These findings suggest that presentation was well-received and enhanced students' understanding of the topic and providing real-world connections through guest speaker (Students 10 and 13) improved the overall student perception of the relevance of course material.

### 3.1.1 Feedback from the students collected through the ‘Minute Paper’ Active Learning Exercise

Table 1 below lists select student responses collected through the Minute Paper active learning activity that is done at the end of each class.

**Table 1:** Summary of Student Responses

| Response No. | Response statement collected through the Minute Paper activity |
|---|---|
| 1 | The speaker was very intelligent and knew exactly what she was talking about :) |
| 2 | The presentation on stormwater was very interesting and detailed. |
| 3 | And an interesting thing about today's class was the presentation about stormwater management. |
| 4 | We had a young lady come to class today, and she did a presentation on Stormwater Management. |
| 5 | It was interesting to learn about how to design green infrastructure |
| 6 | I really enjoyed the guest presentation, she did very well speaking and presenting very good information that she seems very knowledgeable about. I can see why you chose her to do this presentation for us |
| 7 | I really enjoyed the guest lecturer's presentation. It reinforced much of what we've learned and enhanced my understanding of stormwater management. |
| 8 | I really enjoyed having the guest speaker in class today. I felt it was a good learning point for both parties and gained more knowledge on Stormwater management. She did a great job presenting but can use more practice to really keep the class's attention. |
| 9 | it was interesting to learn how to design GIs and the different types that exist. |
| 10 | It was nice to have the guest speaker here to see actual real-life applications of stormwater management. They really drove home the point and scope of what they do well. It was a good change of pace to the course I enjoyed the class |
| 11 | Was a good presentation |
| 12 | Had the guest speaker today. I found the different types of GIs to be very interesting, particularly Bioretention basins. |
| 13 | Today's lecture was very interesting with the guest speaker. I liked how in-depth they went to go over bioretention systems and found it an interesting way to learn new material. I think guest speakers are a fun way to learn certain material related to the class. |

### 3.2. Research Term Papers for an Introductory Undergraduate Class (Summer 2022)

The target course for this case study was a sophomore level introductory course in environmental engineering (ENE 262 Introduction to Environmental Engineering). Like case study 1, this course also covers relevant topics in the syllabus, and inclusion of new topic: Green Infrastructure for Stormwater Mitigation and Pollution Control was a simple addition. This course also has a comprehensive term paper requirement where the students were expected to conduct literature reviews on the topics that are not covered in great depth during the class and make a presentation on their findings. This term paper requirement was instrumental for us to cover the research topic in greater detail as compared to the earlier case study. We also utilized a combination of active learning techniques. At first, we provided a short write-up to the students on the "Urban

Stormwater Management and Microplastics in Stormwater" prior to the class emphasizing on the runoff created due to increased urbanization and how pollutants could be transported via runoff. After reading the document, the students had to choose a topic based on their interest for their term paper. The doctoral candidate presented a short overview and participated in an engaging discussion with the class to help them finalize the outline of their research. During this session, the students came up with multiple interesting questions and discussions to narrow down and finalize their topic to write the term paper. This activity not only led to the discussion on stormwater, microplastics, but also other environmental challenges like Harmful Algal Blooms.

**The topics of terms papers chosen by students:**

1. Stormwater Pollution's Impact on River Water Quality and Methods for Mitigation
2. Residential Stormwater Management
3. Influences of River Hydraulics and Hydrology on Harmful Algal Blooms: A Clearer Picture of River Pollution

In these papers, students explored various aspects of environmental engineering beyond the standard curriculum. The first paper addressed river pollution and stormwater pollutants, offering insights into potential mitigation strategies. The second paper highlighted the importance of stormwater management in residential areas, suggesting economically viable solutions. The third paper examined the relationship between nutrient loads in rivers and factors such as flow rate and temperature, illustrating their impact on algal blooms.

This approach not only facilitated a comprehensive understanding of the topic presented but also significantly enhanced students' grasp of the subject matter through prior research and follow-up discussions. This approach deepened students' engagement and understanding of environmental issues by enhancing their critical thinking and research skills, allowing them to confidently analyze and discuss complex topics. The success of this approach was reflected in the students' ability to articulate their understanding of the topics through their term papers and presentations, demonstrating a marked improvement in their comprehension and engagement with the subject. By presenting these non-traditional perspectives and encouraging active participation, we believe, we successfully exposed students to a broader spectrum of current issues, diversified viewpoints, and varied frames of reference, thereby enriching their educational experience and preparing them for future challenges in environmental engineering.

### 3.3. Mentoring Undergraduate Student through Summer Research

Providing undergraduate students with hands-on research opportunities and mentorship in environmental engineering labs has been shown to enrich their

learning and better prepare them for future careers in the field. By working directly with faculty researchers and graduate students on real-world projects, the students can apply classroom knowledge, develop technical skills, and experience the scientific process in a supportive environment. In Summer 2022, the doctoral candidate mentored an undergraduate student for 3 months through the McNair Scholars Program at NJIT. This program is designed to help low-income and underrepresented students majoring in STEM disciplines. During the program duration, the student was assigned a project on "Water Quality investigation of two lakes" for which he was mentored on all research stages i.e., literature review, field sample collection, laboratory analysis, date analysis, critical thinking, and technical writing. This collaborative nature of labs also fostered teamwork, communication, and problem-solving abilities. The student successfully presented his findings at the annual summer student research symposium that brings together student researchers from multiple externally and internally funded programs. This mentorship also helped the student in shaping their professional identities and navigating their career. The student continued to work with us in the lab on microplastics analysis, lake water quality projects and stormwater management. The feedback from the student (section 3.3.1) shows a positive turnaround and an impact of the summer research in Engineering Education.

### 3.3.1 Feedback from the student

*"In 2022, I had my first summer research experience. It was my inaugural venture into the world of research, and I was unsure of what to anticipate. During this time, my doctoral student mentor not only provided me with a comprehensive overview of the project but also guided me through the necessary steps to execute my research successfully. Daily meetings with my mentor allowed me to seek advice and share my progress, and her feedback consistently proved invaluable. Her mentorship transformed this experience into an immensely enjoyable one for me. Thanks to her guidance, my summer work was of such high quality that I was offered a paid position to continue my work at the research center. Since then, I've had the privilege of collaborating with my mentor on various projects, including a research initiative aimed at identifying microplastics within our city's green infrastructure, a project on wetland pollution funded by the NSF, and a project in collaboration with EPA. Today, I aspire to further my education at the graduate level, with research having become one of my passions. I am profoundly grateful to my mentor, for she was the first person to introduce me to the joys of research and remains a pivotal figure in my professional journey."*

## 4. Conclusion

This paper emphasizes the critical need for a paradigm shift in engineering education, where research and coursework become intertwined. Through these

case studies, we observed significant improvements in student engagement, understanding of complex environmental issues, and the ability to apply theoretical knowledge to real-world problems. Students expressed increased interest in the subject matter, as evidenced by positive feedback on guest lectures, active participation in group exercises, and the high quality of term papers and research projects. The case studies also highlighted the effectiveness of active learning strategies in enhancing the educational experience, with students demonstrating a deeper understanding of green infrastructure concepts and their applications in stormwater management. Moreover, the mentorship not only provided hands-on experience in labs but also fostered a passion for research and professional development. These case studies can also be integrated into other research topics beyond Green Infrastructure for Stormwater Mitigation. The future work will focus on identifying the student learning outcomes and quantifying the efficiency of learning outcomes from these methods. Nevertheless, these findings underscore the value of integrating current research topics into engineering courses to cultivate a knowledgeable, skilled, and motivated workforce ready to address future technological challenges. Hence, encouraging educators and policymakers to reconsider the traditional separation between research and education, fostering a more agile and responsive engineering workforce prepared for the challenges of the future.

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