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The Role of Pairing Sustainability with Innovation Driven Learning: Observation on the Application of the Engineering-for-One-Planet Framework Guided by the Renaissance Foundry Model

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Abstract

This work in progress investigates how the role of an educational intervention that coupled sustainability principles with an innovation-driven learning platform guides students through the development of a protype of innovative technology. Specifically, the intervention includes the purposeful pairing of the Engineering for One Planet (EOP) framework[1] with the Renaissance Foundry model (i.e., the Foundry)[2] in an undergraduate chemical engineering course that requires student teams to address societal challenges as learning outcomes. We argue that pairing the EOP framework with the Foundry results in an increase in students' sustainability efforts in the design of their prototype of innovative technology that addresses identified societal challenges. A preliminary analysis is presented comparing outcomes from two semesters of the CHE 3550, Transfer Science II (Fluids), course, which is a three-credit hour course with an additional one credit of laboratory work (CHE 3551). Preliminary implications related to holistic engineering education efforts and socially relevant learning will be presented and discussed.

Keywords

Sustainability, Engineering for One Planet, Renaissance Foundry Model, Holistic Professional, Foundry-guided learning

Introduction

Recent efforts at the turn of the century have focused on transforming engineering educational programs and foundations (e.g., VentureWell, The Lemelson Foundation, *inter alia*) to incorporate principles of sustainability into the design thinking process of engineering systems, products, and processes.[1, 3, 4] This type of training intentionally integrates sustainability principles that focus on key aspects of environmentally responsible models that efficiently address complex social challenges.[4, 5] In this respect, sustainability efforts focus on maintaining the balance of a particular system, process, or function that does not negatively interrupt natural resources or processes inherent to the environment.[1, 3, 5] Thus, current efforts within our department that are related to sustainability center on enhancing students' understanding of the principles related to these efforts and how they influence innovative design solutions that are both socially and environmentally sustainable.

The work-in-progress presented in this contribution explores the mechanics between incorporating the Engineering for One Planet (EOP) framework and a Foundry-guided course design.[6, 7] Specifically, we look at efforts undertaken in previous iterations of CHE 3551, Transfer Science II (Fluids), a three-credit hour course with one credit of lab work offered at a medium-sized, rural, public, four-year university, that inspired the redesign of the course with respect to sustainability. In each of these iterations, prototypes of innovative technology developed by student teams that address societal challenges are a required outcome.[6, 7] Preliminary findings from our previous work identified how students that were exposed to this integrated pedagogical strategy advanced their incorporation of key sustainability principles within the design process of their final prototype of innovative technology.[6, 7, 8] This study provides a statistical distribution comparison of data collected in efforts to magnify the focus on sustainability in this undergraduate chemical engineering course.

Brief Overview of Integrated Pedagogical Strategies

The Renaissance Foundry Model

Engineering education has been moving towards the integration of fundamentals of sustainability within the curricula; however, despite these efforts, scholarship still indicates that systematic models offering a comprehensive integration of sustainability efforts that result in the development of holistic engineering professionals is still needed. [1, 3, 6, 9] In response to this need, the efforts at our institution have focused on developing a pedagogical framework that effectively integrates the use of teamwork, innovation, prototype development and challenge identification known as the Renaissance Foundry Model (i.e., the Foundry).[2] The theory and pedagogical foundations of the Foundry are beyond the scope of this work and have been described in detail within extant literature.[2, 6, 7] A brief description of the model is provided here to better understand how it was paired with the EOP as an integrated approach.

The Foundry is an innovative-driven platform that is centered on students collaborating in teams to achieve a learning and design process from identifying a challenge and moving this towards the development of a Prototype of Innovative Technology. This process is based on six key elements that are organized in two main paradigms, i.e., the Knowledge Acquisition Paradigm and the Knowledge Transfer Paradigm.[2] The central pivotal element of the Foundry is the "Resources" that are common to both paradigms. In addition, the Knowledge Acquisition Paradigm features the Learning Cycles, and the Organizational Tools which are both preceded by the Challenge identification. The Knowledge Transfer Paradigm is chiefly built on the Linear Engineering Sequence that is followed by the Prototype of Innovative Technology as the outcome of the platform.[2] One key feature of the Foundry is that it is centered on student teams.

The contextual element of this study, featuring the CHE 3551 course, was designed using the Foundry which provided the guidance necessary for the development of a prototype of innovative technology, centered on the sustainability principles featured in the EOP framework.

EOP Framework

The EOP framework is a comprehensive taxonomy of a systems thinking approach that outlines nine key principles of sustainability and their respective learning outcomes to better enhance students' understanding of sustainability concepts.[1, 10] The nine principles of sustainability presented by the EOP include: Systems Thinking, Communication and Teamwork, Environmental Literacy, Responsible Business and Economy, Social Responsibility, Environmental Impact Assessment, Materials Selection, Design, Critical Thinking.[1] Further, we found that these key principles align with key elements of the Foundry (e.g., Critical thinking, Communication, Teamwork, Design, Social Responsibility, Systems thinking) that can be leveraged as part of the integration of both frameworks into the development of an educational environment that assists in the formation of holistic professionals. For example, we noted that the outer sphere of the framework which encompassed the development of skills related to critical thinking, social responsibility, materials choices, design, and communication/teamwork, *inter alia*, were closely aligned to the skills being developed as part of the iterative phases of the Knowledge Acquisition and Knowledge Transfer Paradigms in the Foundry.[2, 6, 7] The central sphere, designated to systems thinking, however provides a focus wherein students' efforts to develop a prototype of innovative technology in these courses can be centralized and enhance their efforts to include sustainability in design. [6, 7]

Integration and Preliminary Analysis

Supported by a mini grant from the American Society for Engineering Education in partnership with the Lemelson Foundation, efforts concerning the integration of the EOP in the redesign of the CHE 3551 course were implemented during the Spring 2023 semester. Specifically, the intervention featured a paired pedagogical approach that combined the EOP Framework and Foundry-guided course design and required student teams to address societal challenges as learning outcomes. In particular, intentional activities that asked student-teams to leverage the EOP framework as a way of integrating approaches to systems thinking, knowledge and understanding, skills, experiences, and behavior as part of the design processes within Foundry-guided learning experiences were pivotal to enhance this learning environment.

This study's research design adopts a primarily quantitative approach that leverages descriptive data collected from an EOP designed rubric from two semesters: one prior to, and one during, the EOP framework integration into a Foundry-guided course. Table 1 illustrates the number of students and total projects represented in this analysis from both semesters in the analysis.

Table 1: Overview of Data from Semester 1 and Semester 2

	Semester 1 (pre-EOP)	**Semester 2 (post-EOP)**
Total Projects	20	11
Students	60	33

This comparison focuses on general distribution data from this rubric to understand differences in the way students incorporated the EOP principles as part of their prototype of innovative technology. The rubric that was utilized reflected students' performance at five levels representative of Poor to Excellent, with each integrating more elements of the Learning Outcomes associated with the EOP Principles as they reach the highest level (i.e., Excellent). Figure 1 illustrates the differences in student scores for Semester 1 and Semester 2 for the nine EOP sustainability topics as based on a performance of Excellent on the rubric. Overwhelmingly, students in Semester 2 (Post-EOP) integrated the EOP Principles in their prototypes of innovative technology at higher rates at the level of Excellent in comparison to students in Semester 1 (Pre-EOP). Based on the preliminary general distribution analysis, there is evidence that the integration of the EOP framework as a structured approach to sustainable design generally helped student-teams develop prototypes that addressed societal challenges as part of their formation as holistically trained professionals.

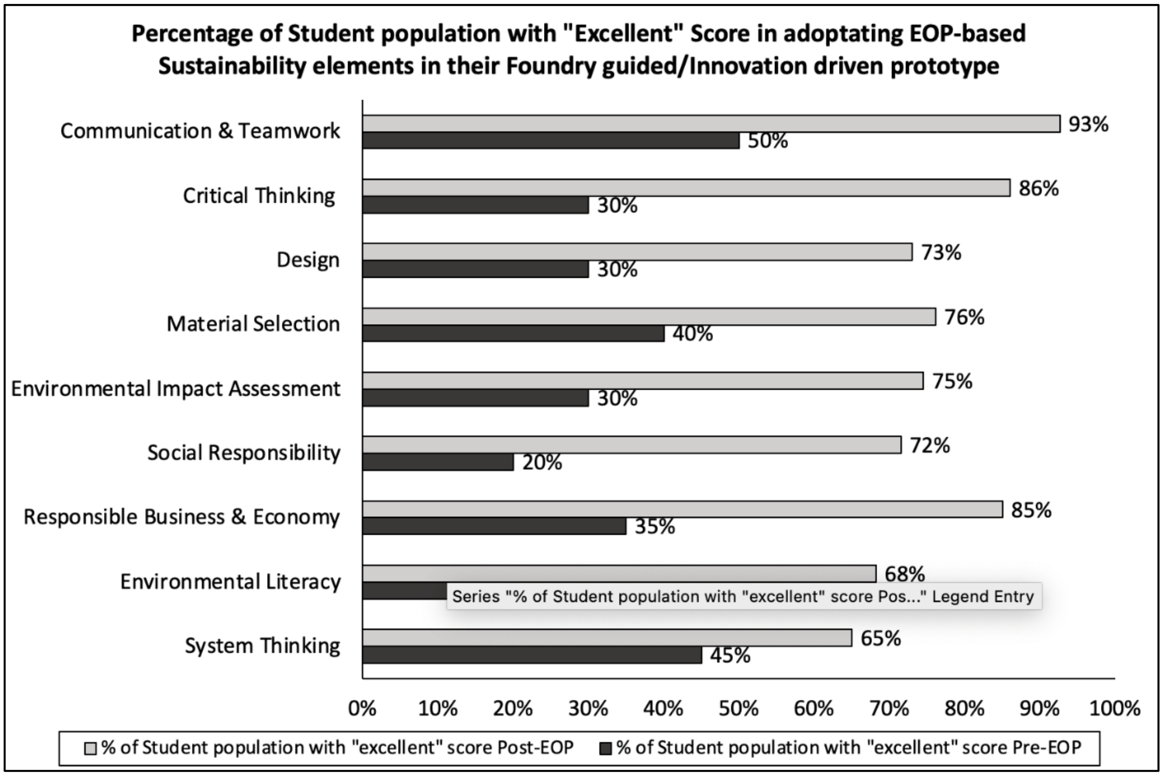

Figure 1: Pre and Post Comparison of Percentage of Students with "Excellent" Score on EOP Principles.[10]

Current Work and Next Steps

As this is a work-in-progress, there are several takeaways that can be investigated further. Concerning research, inferential analysis is needed to ascertain if the differences in performance are statistically significant. Further, after appropriate ethical considerations are obtained, we intend to investigate student perceptions of the role of the EOP framework on sustainability and biomimicry design as part of the implementation efforts. This research will also be integral to the work of current doctoral students interested in engineering education and will expand upon student learning efforts pertaining to the Foundry.

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