Work in Progress: Teaching Engineering Students to Self-Transform: Parallelisms between Product Innovation and Student Career Path Planning

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Abstract

Freshman engineering students can have a hard time transitioning to college. The freshman year is critical to the students' academic success; in this year they learn basic skills and establish essential networks with other students, faculty, and resources. How can we help these freshman engineering students in this transition? We propose that freshman students can learn from the engineering design innovation process and apply it by analogy to the design of their academic pathways. There are multiple similarities between product innovation (i.e., technology) and the continuous academic challenges faced by the student. Engineers as designers and innovators have a vast and rich repository of techniques, tools, and approaches to develop new technologies, and a parallelism can be drawn between the design and innovation of a technology (e.g., redesign of a kitchen appliance), and the "design" of the students' academic career pathways. During the Spring 2023 semester pilot, students in Intro to Mechanical Engineering (Course A) worked in teams in a 6-week product innovation project to redesign a simple kitchen appliance. Students learned basic concepts of the design process (e.g., creative exploration of solutions, decision making, multi objective evaluation, etc.). These same students concurrently took Course B (Learning Frameworks) where they worked on a 6-week project to define their career pathways. Both projects, product innovation and career pathways, followed the Challenge Based Instruction (CBI) approach. Periodically, participant students were shown how to use the lessons from product innovation by analogy and reflection in their career pathways project. The objective is for students to learn about the engineering design process and to apply it to their academic challenges by analogy. This prepares students with meta skills to help solve future problems in their academic path, and at each iteration, the students transform themselves, hence the use of the term self-transformation (also referred as "self-innovation"). Data collected from pre and post surveys will be presented to measure self-efficacy in engineering design, grit, motivation to learn, and STEM identity. Participant interviews provide a qualitative insight into the intervention. This project is funded by NSF award 2225247.

Introduction

In recent years, the transition of freshman engineering students into college has emerged as a critical concern within academic circles. The freshman year serves as a foundational period during which students acquire essential skills and establish crucial networks with peers, faculty, and resources. However, many freshmen encounter challenges adapting to the rigors of college life, which can impact their academic success and overall well-being [1-9]. Recognizing the significance of this transition period, our project aims to address the needs of freshman engineering students as they navigate their academic and career pathways. Engineers possess expertise in the intricate design of innovative products, a task enriched by a robust background in effective design, innovation, and entrepreneurship within the technical realm. The concept of Design Thinking has expanded the application of the technical design process beyond traditional boundaries, encompassing domains such as economics, government, and management. Thus, it becomes plausible to extend this framework to undergraduate STEM students, facilitating a

process of self-design, self-innovation, and self-transformation, wherein the student assumes the role of the designer and their academic path becomes the product [10-16]. While acknowledging that students are far from being simple products, the analogy offers valuable insights. Our students bring forth a diverse array of skills and face an array of challenges. Some students struggle with framing their problems, exhibit reluctance in seeking assistance, and lack clarity in charting their academic success trajectory, among other issues. Analogously, a designer follows a structured process to tackle similar issues in creating a successful product. Moreover, the dynamic nature of the challenges students encounter presents a clear innovation challenge, necessitating adaptability and creativity in problem-solving. The primary focus of our project is to facilitate the transition of freshman engineering students by drawing parallels between the engineering design innovation process and the design of their academic pathways. This innovative approach is grounded in the belief that students can learn valuable lessons from the engineering design process and apply them analogously to their academic and career planning. By leveraging the principles of design thinking, students can gain meta-skills that empower them to tackle academic challenges with creativity, resilience, and adaptability. The significance of our project lies in its potential to equip freshman engineering students with the necessary tools and mindset to navigate the complexities of their academic and career journeys successfully. By integrating principles of design thinking into the curriculum, we aim to foster a culture of innovation, problem-solving, and self-reflection among students. Through hands-on projects and experiential learning opportunities, students will not only gain a deeper understanding of engineering design but also develop essential skills for personal and professional growth. Our work builds upon existing literature in the fields of engineering education, design thinking, and student development. Numerous studies have highlighted the importance of providing support and resources to help freshman students transition successfully into college life [10-16]. However, few have explored the potential application of engineering design principles to address the unique challenges faced by freshman engineering students. By bridging these two domains, our project contributes to a growing body of literature aimed at enhancing student success and retention in engineering programs. While our project holds promise for improving the transition experience of freshman engineering students, it is not without its limitations. The scope of our study is confined to a single academic institution (UTRGV) and a specific cohort of students enrolled in introductory engineering courses. Additionally, the implementation of design thinking principles in the curriculum may require additional resources and faculty training. Despite these limitations, we believe that our project has the potential to yield valuable insights and serve as a model for other institutions seeking to support the success of freshman engineering students.

Project Approach

The project approach employed in this study aimed to integrate engineering design principles into freshman engineering education to facilitate self-transformation and enhance academic and career readiness. The study involved freshman engineering students enrolled in Intro to Mechanical Engineering (Course A) and Learning Frameworks (Course B) during the Fall 2023 semester. Participants were recruited from the UTRGV campus, and consent was obtained prior to their involvement in the study. The methodology involved a structured intervention

implemented in two courses. A comparison of Course A and Course B activities is presented in Table 1.

Table 1. FYIE Courses-Projects Coordination.

Challenge Based Instruction	MECE 1101 Intro to Mech. Eng. Tech Design Innovation Project	Self-Transformation Adaptive Expertise Written Reflective Journal Guided Reflection Sessions Daily Journaling	UNIV 1301 Learning Framework Academic Pathways Project
The Challenge: Problem Definition	Problem Formulation		Motivation
Generate Ideas: Brainstorm	Product Dissection		Visualizing your Future Self
Multiple Perspectives and Resources: Consult Experts, Books, etc.	Design Exploration		Investigate Paths
Research and Revise: Solution Design and Specs	Design Optimization		Define your Path
Test Your Mettle: Test and Revise Prototype	Test and Validation		Will it Work?
Go Public: Final Product & Report	Report, Presentation, & Video		Report, Presentation, & Video
Adaptive Expertise: Reflect & Redesign	→		←

Course A: Product Innovation Project: Students from Course A participated in a 6-week project focusing on product innovation by redesigning a simple kitchen appliance. Students were organized into teams to encourage collaboration and diverse perspectives in the design process. The project followed the Challenge Based Instruction (CBI) approach, emphasizing active learning, problem-solving, and real-world application. Basic concepts of the design process, including creative exploration of solutions, decision-making, and multi-objective evaluation, were covered. Students utilized design tools and techniques to ideate, prototype, and iterate their appliance redesign, guided by instructors. Regular reflection sessions encouraged students to draw parallels between product innovation and their academic pathways, fostering self-transformation through iterative learning experiences.

Course B: Academic & Career Pathway Project: This project focused on guiding Course B students in defining their academic and career pathways over a 6-week period. Students engaged in self-reflection and goal-setting exercises to identify their academic interests, strengths, and career aspirations. Analogous to Course A, the project adopted the CBI approach, emphasizing active participation and real-world relevance. Students explored various academic and career opportunities within the field of engineering, considering factors such as specialization areas, industry trends, and personal values. Faculty provided guidance and support throughout the project, assisting students in navigating academic and career-related decisions. Students were encouraged to apply lessons learned from the product innovation project to their career pathways, fostering a holistic understanding of the engineering design process and its applicability to personal and professional development.

Data Collection Instruments: For the present study, data collected from the Learning Frameworks course (Course B) served as a pivotal parameter for assessing the efficacy of the intervention. This course was designed to complement the Academic & Career Pathway Project,

providing students with the necessary skills and knowledge to navigate their academic and career pathways successfully. Through an analysis of the data collected from Course B, we aim to evaluate the impact of the intervention on student learning outcomes, self-awareness, and academic success. The data collected from Course B includes a demographic survey, student self-reflection post-survey, and academic performance metrics. These data sources provide valuable student development and learning insights throughout the semester.

Demographic Survey: The study included a demographic survey that was crucial for capturing a complete understanding of the student population's background. The survey mainly focused on gathering data related to the students' gender and ethnicity, which are essential for analyzing diversity within the course and assessing whether different demographic groups experience the course content differently. Additionally, the survey collected information about the highest educational degrees attained by the student's parents. This aspect of the survey is particularly valuable as it provides insights into the students' socioeconomic backgrounds, which could influence their access to educational resources and support. By understanding these variables, the survey will help to interpret the impact of the educational interventions and the student's responses to them, ensuring that the findings are viewed through the lens of this vital contextual information.

Deliverables: The Academic & Career Pathway Project delivered student individual self-reflections and academic and career presentations. These deliverables offered opportunities for students to engage in reflective practices, communicate their pathway plans effectively, and receive constructive feedback from peers and instructors. By completing these tasks, students gained valuable insights into their academic and career aspirations and developed essential skills for professional development and self-awareness.

Self-Reflections: The individual self-reflection objective was to articulate personal insights gained from the pathway planning process and self-discovery. After researching career options and developing a plan for their pathway, students reflected on what they learned about the process and themselves. Each student undertook an individual reflection exercise following research on career options and developing a pathway plan. Reflections covered topics such as experiences during research, factors influencing pathway decisions, identified strengths and areas for growth, and the significance of the process in shaping academic and career aspirations. Written reflections were submitted individually, providing a platform for students to express their thoughts and reflections in a structured manner. The reflections were assessed based on depth of insight, clarity of expression, relevance to the pathway planning process, and alignment with personal goals. A survey was administered along with the individual reflections, including the questions in Table 1.

Academic & Career Team Presentations. This activity aimed to communicate pathway plans effectively, showcase research findings, and receive feedback from peers and instructors. Students collaborated in small teams to present their Academic & Career Pathway Plans to classmates and the instructor. The presentations included an overview of chosen career options, the rationale behind pathway choices, academic goals, extracurricular activities, and plans for professional development. The team presentations were conducted in a seminar-style format,

allowing for interactive discussion and Q&A sessions. The presentations were evaluated based on clarity of communication, coherence of content, depth of research, alignment with pathway objectives, and ability to respond to questions and feedback effectively. These deliverables provided opportunities for students to engage in reflective practices, communicate their pathway plans effectively and receive constructive feedback from peers and instructors. By completing these tasks, students gained valuable insights into their academic and career aspirations and developed essential skills for professional development and self-awareness. In addition, this project approach was approved by the Institutional Review Board IRB-24-0170 and adhered to ethical guidelines for research involving human subjects. The detailed methodology provided a structured framework for implementing the intervention and evaluating its impact on students' self-transformation and academic journey.

Table 1. Self-reflection post-survey questions for Academic & Career Pathway Project.

No.	Question
1	Describe what you learned specifically from conducting this Academic & Career Pathway Project including the assignments, activities, guest speakers, and career presentations. Be specific in your explanation of what you learned.
2	Describe what you learned about yourself and your strengths from creating your career plan and pathway.
3	Describe something you accomplished this fall semester in college that you are most proud about yourself (can be academic, personal, or professional).
4	What other activities, topics, and/or discussions do you recommend including in this Academic & Career Pathway project to learn about your future career?
5	Describe something that was helpful for you from Learning Frameworks course based on the assignments, activities, discussions, and collaborating with classmates.

Results and Discussion

Preliminary findings from the self-reflection post-survey questions for the Learning Frameworks course provided valuable insights into student perceptions and experiences regarding the Academic & Career Pathway Project. The surveys collected from students were analyzed to identify common themes and trends, which are discussed below.

Demographic Distribution

The ethnicity distribution of the study is presented in Figure 1. In the demographic survey, 28 students provided information on their ethnic backgrounds, revealing a predominantly Hispanic composition. A striking 89.29% of the respondents identified as Hispanic, underscoring the group's substantial majority within the student demographic. White/Caucasian students were represented by a modest 7.14%, and a single individual, making up 3.57% of the population, identified as American Indian or Alaskan Native. The disproportionate representation highlights the preeminence of Hispanic students in this educational setting and suggests a particular cultural context that may influence classroom dynamics and learning experiences. The data presented in Figure 2 indicates the highest level of education attained by the parents of the students. For the mothers of participating students, college degrees represent the highest level of education achieved, with 39.29% having attained this level. High school completion follows closely,

constituting 35.71% of mothers' highest education. Advanced degrees, such as master's, are held by 17.86%, while middle school education is less common, reported by 3.57%. A small fraction of students, at 3.57%, indicated they do not know their mother's highest educational attainment. In contrast, the fathers' highest educational attainment is predominantly at the high school level, with half of the respondents' fathers (50%) having this as their highest degree. College degrees are held by 21.43%, and master's degrees by 14.29% of fathers. Similar to mothers, middle school is the least common education level, at 3.57%. A notably higher uncertainty exists regarding fathers' education, with 10.71% of students uncertain about their fathers' highest degree. These figures indicate that a significant portion of parents have achieved secondary and tertiary education, with a higher incidence of high school completion among fathers and greater college degree attainment among mothers.

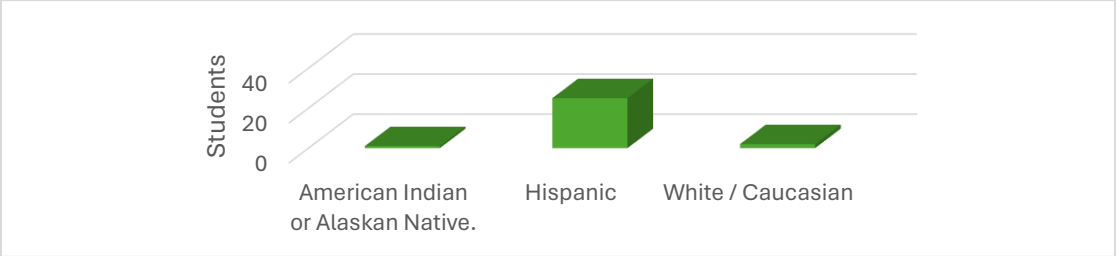

Figure 1. Ethnicity distribution.

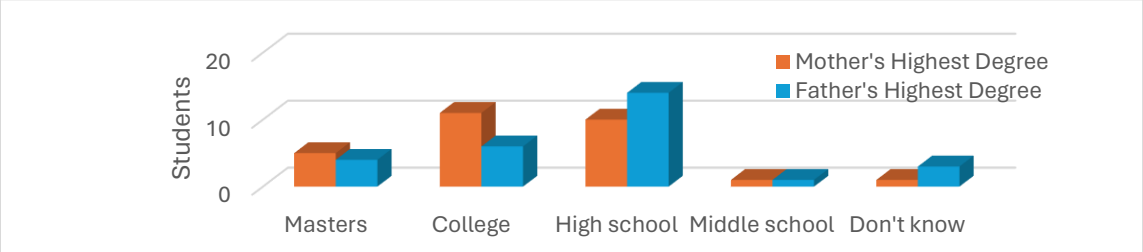

Figure 2. Parent's highest degree attained.

The demographic survey of the student cohort highlights a significant Hispanic majority, with nearly 90% of students identifying with this ethnicity. This could have important implications for the educational environment and dynamics within this group. In stark contrast, White/Caucasian and American Indian or Alaskan Native representation is considerably lower, pointing to a less ethnically diverse student body than might be seen in other educational settings. As depicted in the survey, parental education levels show that a higher education pursuit is common among this group of students' families. Most notably, mothers tend to have higher levels of college completion, while fathers more frequently report high school as their highest level of education. A small but noteworthy percentage of students are unaware of their parents' educational backgrounds, particularly their fathers', suggesting potential gaps in familial educational communication or knowledge. Overall, these demographic findings offer a snapshot of the students' backgrounds and provide a context for understanding their educational experiences and perspectives. They underscore the importance of recognizing and addressing the unique cultural and academic backgrounds students bring to their learning journey.

Self-Reflections: The self-reflection survey results are presented below. After exploring various career options and planning for their future, the students took some time to reflect on their personal growth and the discoveries they made throughout this process. This introspective practice was individualized and followed their research into different career paths, as well as their efforts to chart a roadmap for their journey. During this reflection, the students pondered on the factors that influenced their choices, the strengths they recognized in themselves, and areas where they need development. They also understood the importance of this self-exploration in shaping their academic and vocational ambitions.

Learning from Academic & Career Pathway Project. Students highlighted the importance of university resources in supporting their academic and career aspirations. They learned to actively seek assistance and guidance, recognizing the value of participating in their own growth. Specific lessons included understanding resume building, utilizing career center services, and gaining motivation from guest speakers. One student reflected, "I learned that being ahead of everything and making a plan so that I won't be confused about my future."

Self-Discovery and Strengths. Through the pathway planning process, students gained insights into their personal strengths and areas for growth. While some discovered their enthusiasm for active participation and contribution in their chosen field, others recognized tendencies towards procrastination. Honesty, communication skills, and commitment emerged as notable strengths among the participants. Upon reflecting on their educational path, a student remarked, "Something I learned about myself while creating my career plan is I'm excited about actively participating in my career and as I progress in my education I see myself not only as a learner but as a contributor too. I am eager to apply the knowledge and skills I acquire to make meaningful contributions to my field".

Accomplishments during Fall Semester. Students reported various accomplishments during the fall semester, ranging from academic achievements to personal growth. Maintaining high grades while balancing personal and academic commitments, learning to calculate GPA, and passing all courses with satisfactory grades were highlighted as significant achievements. One student stated, "I'm proud to share that this fall semester, I successfully maintained high grades in all of my classes, and what is even more fulfilling is that I found a balance that allowed me to spend quality time with both my friends and family. since initially I was concerned that focusing on academic success might mean neglecting my relationships with the people I cared about, but I'm pleased to say that I managed both and prioritized both aspects effectively".

Recommendations for Future Activities. Students provided suggestions for enhancing the Academic & Career Pathway project, including incorporating hands-on experiences, interview preparation, and teaching elevator pitches. These recommendations underscore the importance of practical learning experiences and skill-building activities in preparing students for future career endeavors. One student shared their insights by stating, "I believe that the Academic & Career Pathway project inherently offers a comprehensive insight into the specifics of my chosen field. The project originally was designed to dive into the intricacies of my academic journey and career aspirations. While I initially thought additional topics might be necessary I've realized that the project covers a lot of information already".

Usefulness of Learning Frameworks course. The Learning Frameworks course was perceived as highly beneficial, providing valuable insights into college life and introducing students to campus resources. Participants appreciated the assignments, activities, and discussions that facilitated their research on careers and understanding of available resources, ultimately contributing to their academic and personal development. As one student articulated, ". Everything was helpful with both academically and personally like with this career project it helped me research my career and what it takes to achieve it".

These preliminary results suggest that the Academic & Career Pathway Project has been effective in providing students with valuable insights into their academic and career aspirations, fostering self-awareness, and enhancing their readiness for future endeavors. However, further analysis and interpretation of the survey data are needed to draw conclusive findings and identify areas for improvement in future iterations of the project. Further qualitative analysis, such as interviews with students, may provide deeper insights into the impact of the project on student learning and development.

Conclusions

In conclusion, our exploration of the parallelisms between product innovation and student career path planning has unveiled profound insights into the potential synergy between these seemingly disparate domains. Through the lens of engineering design innovation, we have elucidated the striking similarities between the iterative process of developing new technologies and the continuous challenges faced by students in shaping their academic and career pathways. By adopting a Challenge Based Instruction (CBI) approach, students engaged in hands-on projects to redesign simple kitchen appliances, concurrently defining their career pathways. The iterative nature of both endeavors emphasized the importance of creative exploration, decision-making, and multi-objective evaluation in achieving desired outcomes. Furthermore, the integration of reflection exercises enabled students to draw parallels between their experiences in product innovation and their own personal growth and development. By articulating personal insights gained from the pathway planning process, students were able to recognize their strengths, areas for growth, and the significance of their journey in shaping their academic and career aspirations. Through the Academic & Career Pathway Project, students not only gained valuable insights into their individual strengths and aspirations but also developed essential skills for professional development and self-awareness. The findings from the Self-reflection post-survey questions for the Learning Frameworks course shed light on the effectiveness of the Academic & Career Pathway Project in facilitating student self-awareness, exploration of academic and career aspirations, and utilization of university resources. In essence, the parallels between product innovation and student career path planning underscore the transformative power of applying engineering design principles to personal and professional development.

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