Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
ASEE
Paper ID #47232

BOARD # 175: A Novel Teaching Strategy for Integrating Freshman and High School Students in Introductory Mechanical Engineering

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WIP: A Novel Teaching Strategy for Integrating First-Year College Students and High School Students in Introductory Mechanical Engineering

1. Introduction

Many universities offer dual enrollment programs to encourage high school students to take college-level courses [1]. Research has shown that dual enrollment programs can lead to improved academic performance, as evidenced by higher college GPAs [2, 3]. Additionally, dual enrollment has been found to positively impact time-to-degree completion [4]. Furthermore, studies indicate that dual enrollment predicts better college enrollment, persistence, and completion rates [5].

Despite these benefits, mixed-level learning environments—where both high school and college students enroll in the same courses—present unique challenges and opportunities for instructors. These settings require teaching strategies that bridge the gap between differing levels of prior knowledge and learning readiness. High school students often lack foundational knowledge in engineering topics, while college freshmen expect more rigorous content. Addressing these needs effectively requires innovative approaches that promote inclusivity, collaboration, and active engagement.

Differentiated learning strategies have been shown to significantly improve outcomes in diverse classrooms by tailoring content, process, and assessments to accommodate varying levels of readiness, interest, and learning profiles [6]. Collaborative teaching methods, such as project-based learning (PBL), enhance student engagement and foster critical thinking by allowing students to work together on real-world problems [7]. Peer learning, in which more experienced students mentor those with less experience, can create a mutually beneficial learning dynamic [8].

To address these challenges, we developed a novel teaching strategy for an introductory engineering course that integrates high school students with first-year college students. This course, titled "Introduction to Engineering Laboratory" aimed to expose students to various engineering disciplines through hands-on experiments and collaborative projects. The ultimate goal was to foster motivation, build foundational knowledge, and help students make informed decisions about their future career paths.

The course was structured as a rotational program, with students spending three weeks in each of four engineering modules: mechanical, electrical, computer, and civil engineering. Each module incorporated hands-on activities, group projects, and career exploration discussions to provide a comprehensive introduction to the field. This paper focuses on the mechanical engineering module, where we implemented three key teaching strategies: (1) Differentiated Learning Pathways, (2) Collaborative Project-Based Learning (PBL), and (3) Adaptive Assessment and Feedback. These strategies were designed to address the diverse academic needs of mixed-level learners while promoting collaboration, motivation, and effective learning.

The mechanical engineering module included activities such as tensile testing of materials, hardness testing before and after cold work, and CAD design using SolidWorks. These labs were selected to showcase fundamental engineering principles while allowing students to engage in hands-on experimentation and creative design tasks.

This study aims to evaluate the effectiveness of this teaching strategy in improving student engagement, confidence, and interest in STEM careers. While the results show short-term gains, the long-term impact, such as retention in STEM fields, remains an open question for future research.

2. Method

2.1 Course Overview

The "Introduction to Engineering Laboratory" course is a rotational, hands-on program designed to introduce students to multiple engineering disciplines. Each module includes hands-on activities tailored to fundamental engineering principles, group projects that promote collaboration and the practical application of theoretical concepts, and career exploration discussions to help guide students in selecting an engineering field. Students spent three weeks in each module, rotating through the four disciplines over the course of the semester. The mechanical engineering module focused on basic mechanics, assembly and design principles, and engineering problem-solving.

2.2 Key Teaching Strategies

The teaching strategy for the mechanical engineering module centered on three pillars:

a) Differentiated Learning Pathways: High school students explored fundamental engineering concepts using accessible examples and interactive demonstrations. First-year college students engaged in deeper exploration, including mathematical modeling and complex problem-solving.

   Modular lessons with tiered objectives allowed both groups to progress at their own pace.

b) Collaborative Project-Based Learning (PBL): Mixed teams of high school and first-year college students worked on engineering projects, balancing theoretical knowledge and practical applications. High school students focused on foundational tasks, while first-year college students assumed leadership roles, facilitating mentorship and peer learning.

c) Adaptive Assessment and Feedback: Multi-layered assessments evaluated students based on their respective skill levels. Peer reviews, self-assessments, and dynamic feedback loops promoted reflection and growth.

2.3 Assessment Methods

The effectiveness of the teaching strategy was evaluated using a survey administered at the end of the semester. The survey assessed various aspects of the course, including engagement, confidence in understanding key concepts, and the perceived value of collaborative activities. A total of 18 students participated in the study: 14 high school students and 4 first-year college students. Future work will expand the dataset to improve statistical reliability.

2.4 Implementation of Teaching Strategies in the Mechanical Engineering Module

Differentiated learning pathways were implemented in this course in three weeks as follows:

Week 1: Tensile Testing of Steel and Aluminum

The objective of this lab is to introduce students to the fundamental concepts of material strength and elasticity through both hands-on demonstrations and data analysis. High school students engaged in guided experiments to explore material strength and calculate elastic modulus from stress-strain curves. First-year college students conducted in-depth mathematical analysis by plotting stress-strain curves from force-displacement data obtained using an Instron universal testing machine after performing uniaxial tensile tests on both materials.

This tiered approach ensured that high school students gained foundational knowledge while college students delved into more complex engineering concepts, fulfilling the objectives of differentiated learning.

Week 2: Hardness Testing of Brass and Copper Plates Before and After Cold Work

The objective of this lab is to investigate how the hardness and ductility of a metal change as it undergoes cold working. During the experiment, the thickness and hardness of 2 different metal strips were measured and recorded after each 5% reduction in thickness until failure occurred. High school students observed changes in material properties and failure behavior through hands-on rolling of specimens, comparing results before and after cold work. First-year college students performed hardness testing, recorded and interpreted hardness values, and linked the results to underlying changes in material structure and mechanical properties.

By tailoring the depth of content for each group, students were able to understand how engineering concepts apply to real-world material design, reinforcing the differentiated learning strategy.

Week 3: CAD Design Using SolidWorks and 3D Printing

High school students designed simple objects and explored pre-existing models to understand the basics of 3D modeling. First-year college students designed more complex CAD models, saved the files using appropriate formats and settings, and completed the process by printing their designs using a 3D printer.

This activity allowed high school students to build confidence with entry-level tools, while college students refined their engineering design skills.

3. Results and discussion

Survey responses revealed that 72% of high school students and 20% of college students reported high engagement levels (Figure 1A). Specifically, approximately 60% of high school students rated the course as "Very Engaging". Regarding peer learning, 71.4% of high school students and about 20% of college students found it beneficial (Figure 1B), with 20% of high school students rating collaboration as "Extremely Valuable". Approximately 80% of high school students indicated that the course methodology significantly or somewhat influenced their interest in engineering disciplines, compared to only 15% of college students (Figure 1C). Additionally, 78.6% of high school students and 50% of college students reported an increase in confidence in engineering concepts (Figure 1D). Among high school students, 30% felt "Confident," whereas only 20% of college students reported the same. Following course completion, 50% of all students noted an increased interest in STEM fields (Figure 1E).

Notably, 60% of high school students expressed being "Very Interested" in STEM after the course, an increase from 42% before the course. Common barriers to pursuing STEM careers included a lack of confidence (61%) and limited knowledge of STEM professions (35%) (Figure 1F). Among high school students, 50% identified lack of confidence as a major barrier, compared to 15% of college students, while 25% of high school students and 7% of college students cited limited knowledge of STEM careers.

Key challenges identified included differences in baseline knowledge and occasional difficulties in balancing the needs of both groups within the same project. To assess the three pillars, survey questions focused on engagement, confidence, and collaboration, which aligned with each pillar's goals. Differentiated Learning Pathways were evaluated through questions about barriers to learning and how well the course matched students' experience levels. Collaborative PBL was assessed through questions on teamwork and group project effectiveness, while Adaptive Assessment and Feedback were evaluated based on students' perceptions of the value and fairness of feedback.

Regarding the course's structure, the rotational format provided an overview of multiple disciplines, ensuring that students received exposure to various engineering fields. The mechanical engineering module's content was carefully designed to cater to mixed-level learners, with clear delineation between foundational and advanced tasks.

The findings highlight the importance of structured peer collaboration and adaptive teaching methods in mixed-level classrooms. While engagement and confidence increased, some students noted that collaboration between high school and college students was sometimes limited. Suggestions for improvement included more structured group interactions and clearer connections between course content and real-world applications.

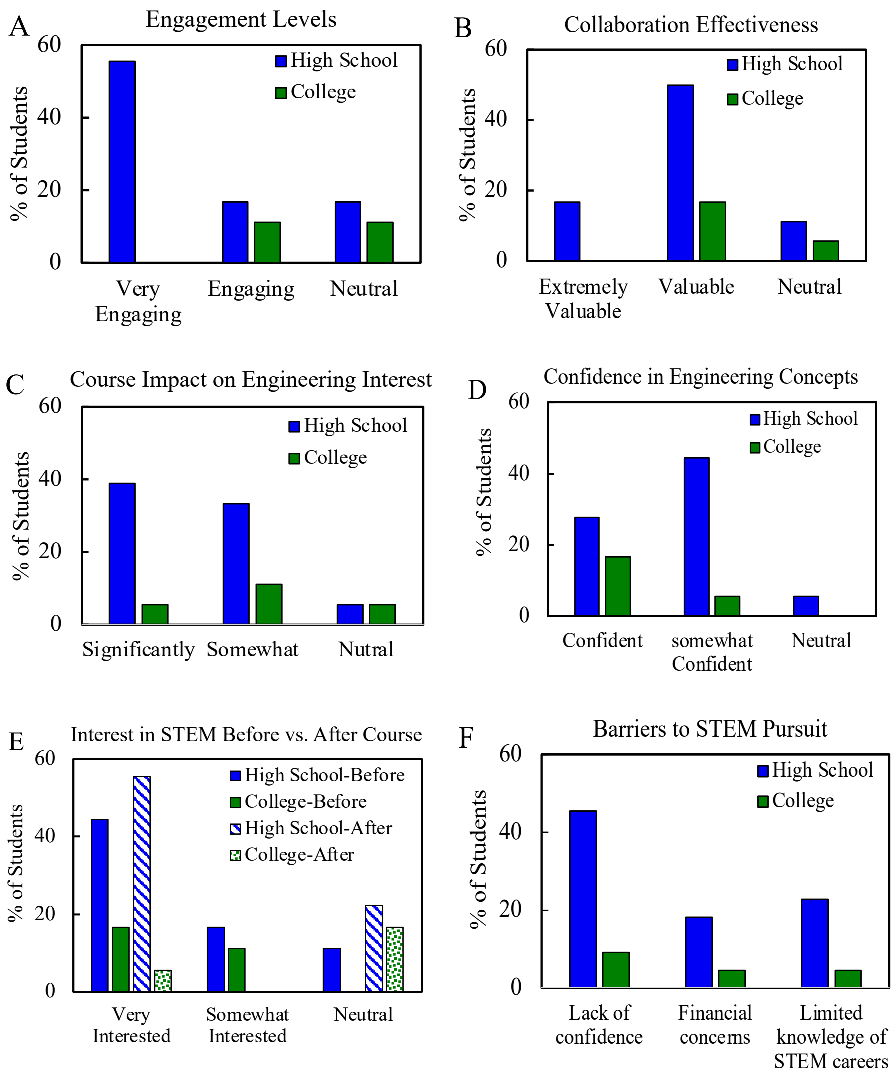

Figure 1. Survey results show: A) student engagement, B) collaboration effectiveness, C) impact on engineering interest, D) confidence in concepts, E) STEM interest before vs. after the course, and F) barriers to STEM pursuit.

4. Conclusions and Future Work

This study demonstrates the potential of differentiated teaching strategies to create an inclusive and effective learning environment for mixed-level engineering courses. The combination of modular lessons and collaborative projects provided students with a well-rounded introduction to engineering. While the sample size is relatively small, the survey results still demonstrate a positive outcome. The findings indicate increased engagement, confidence, and understanding of key concepts, validating the effectiveness of the approach.

Future work will focus on expanding the student sample size to enable robust statistical validation, tracking long-term STEM retention rates, and comparing outcomes with a control group to gain deeper insights into the effectiveness of the implemented strategies.

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