GIFTS: Bridging Engineering Education with a Cost-Effective Classroom Kit: A Hands-On Approach to Active Learning

Introduction

Many first-year engineering students struggle to see the connections among their coursework, often perceiving subjects as isolated. Research shows that integrated curricula not only enhance conceptual understanding but also improve student retention [1], [2]. While integration is more achievable in the first year due to common courses, extending this approach across the curriculum from freshman to junior year remains a significant challenge.

This paper presents a cost-effective, interdisciplinary learning kit that supports active learning through hands-on engagement and cross-course alignment. The kit includes a 3D-printed wind turbine assembled with low-cost mechanical components such as bearings, screws, and fasteners. In MEE 1117 Fundamentals of Mechanical Engineering Design, students measure components with calipers and replicate them in SolidWorks, reinforcing CAD and mechanical design principles. Simultaneously, students in ENGR 1101 Introduction to Engineering use Micro:bit sensors to measure turbine RPM, introducing core instrumentation and programming skills.

The activity scaffolds into upper-level courses: MEE 2305 Instrumentation and Data Acquisition Lab explores dynamic measurements and sensor integration; ENGR 2332 Dynamics introduces kinematic analysis; and MEE 3301 Machine Theory and Design allows students to apply gear ratio and torque calculations. This scalable learning tool connects theoretical and practical learning across multiple levels, fostering student engagement and interdisciplinary thinking from the first year onward.

This contribution aligns with the goals of the GIFTS (Great Ideas for Teaching, and Talking with, Students) initiative, offering a transferable model to enhance active learning and curriculum integration in engineering education.

Materials and Project Approach

This project centers on a cost-effective, accessible classroom kit designed to support hands-on learning across multiple engineering courses. The core of the kit is a 3D-printed assembly that mimics the structure of a wind turbine or motor fan (Fig. 1.). While its primary application is in MEE 1117: Fundamentals of Mechanical Engineering Design, the design is intentionally versatile to allow extension into other courses, supporting cross-level integration from freshman to junior year. The learning kit is composed of readily available, low-cost components, as listed in Table 1.

Table 1. Bill of Materials and Cost Breakdown for One Unit the Learning Kit

#	Component	Approx. Cost [$]	Details
1	3D Printed Parts	1	3D-printed turbine blades and housing
2	Fasteners (Nuts and Screws)	1.50	Standard hardware for assembling turbine components
3	Micro:bit	25	Microcontroller for data acquisition and sensor input
4	Caliper	12	Used by students for precise measurement of components
5	Allen Key	0.30	Tool for assembling mechanical parts
6	Mini Motor	0.7	Provides rotational motion for the turbine
7	Bearing	0.35	Reduces friction and supports smooth shaft rotation
8	Rubber Band	Neglected	Used as a simple belt for pulley transmission

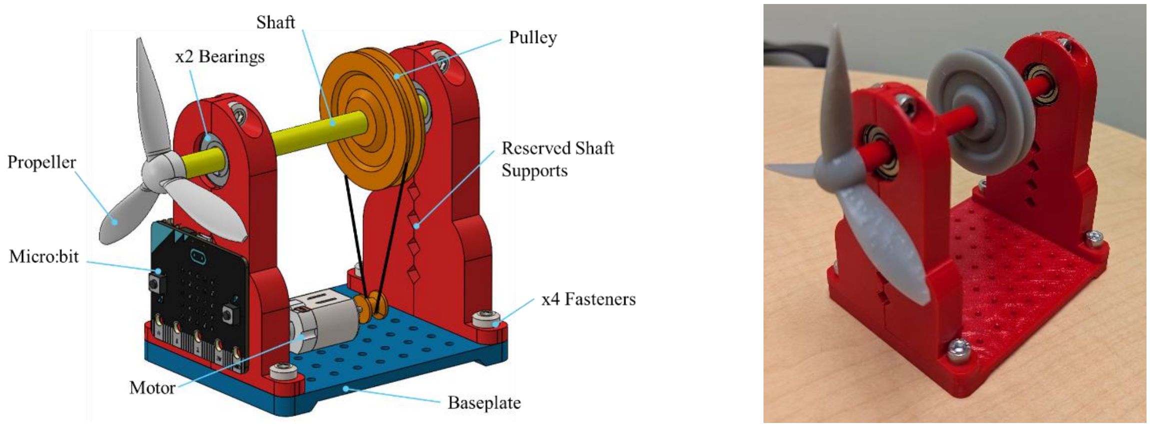

Figure 1. Design of the learning kit and its components (left), and the 3D-printed, assembled version of the kit (right).

Kit Implementation in Courses

MEE 1117 - Fundamentals of Mechanical Engineering Design: In this introductory design course, students use calipers to take precise measurements of the turbine components. They then replicate each part using SolidWorks, applying CAD tools such as extrude boss/cut, linear patterns, bends, assembly, and flex features. Students also utilize the SolidWorks toolbox for inserting standard fasteners. This hands-on experience strengthens design skills and encourages active, peer-based learning.

ENGR 1101 - Introduction to Engineering: Students are introduced to fundamental programming and embedded systems using the Micro:bit microcontroller. Each student receives a Micro:bit as part of their course materials. They use the built-in touch sensors and photodiodes to measure the turbine's RPM. By incorporating pulley ratios between the shaft and the motor, students can also calculate motor RPM, connecting mechanical and electrical principles.

MEE 2305 - Instrumentation and Data Acquisition Lab: This lab focuses on data collection and analysis using sensors. The kit serves as a physical system on which students can measure RPM, displacement, and velocity supporting concepts taught through crank-slider mechanisms and accelerometer/proximity sensor-based data acquisition. The hands-on nature of the kit enhances students' understanding of how theoretical instrumentation principles apply to real systems.

ENGR 2332 – Dynamics: The rotating system at the heart of the kit provides a practical example for analyzing kinematic and dynamic relationships. Students can theoretically model input-output relationships, explore the effects of varying pulley sizes, and even modify the setup to include gearboxes by providing a bridge between physical systems and analytical methods.

MEE 3301 - Machine Theory and Design: At the junior level, students study torque transmission, gear design, and mechanical power systems. The turbine system can be extended with rods and additional 3D-printed components to simulate a gearbox. Students apply theoretical concepts to analyze torque multiplication, gear ratios, and spatial constraints, making the kit a rich case study for mechanical design challenges.

This modular and interdisciplinary design allows the learning kit to be introduced early in the curriculum and revisited in more complex ways as students advance, reinforcing learning while building a sense of continuity throughout the engineering program.

Preliminary Results and Discussion

The interdisciplinary learning kit was piloted as an extra credit assignment in MEE 1117 - Fundamentals of Mechanical Engineering Design at Temple University during Spring 2025. Each group of two students received a kit containing a 3D-printed turbine assembly, a caliper, and an Allen key. Students measured the components using calipers and replicated them in SolidWorks, applying CAD features such as sketching, extrusion, and patterning. While they were not required to model standard components like bearings and fasteners, they researched and imported manufacturer models and toolbox parts, reinforcing real-world design practices. To assess understanding and streamline grading, a quiz was given via Canvas, where each part file was assigned a unique material type and students reported mass properties within a 5% margin of error aligned with the Certified SolidWorks Associate (CSWA) exam, which evaluates students' proficiency in CAD modeling and design analysis. Student feedback indicated high engagement, along with some initial struggles, with many expressing excitement about the realistic, hands-on implementation, improved modeling techniques, and the practical relevance of CAD skills.

References

[1] N. Al-Holou *et al.*, “First-Year Integrated Curricula: Design Alternatives and Examples,” *J. Eng. Educ.*, vol. 88, no. 4, pp. 435–448, 1999, doi: 10.1002/j.2168-9830.1999.tb00471.x.

[2] J. E. Froyd and M. W. Ohland, “Integrated Engineering Curricula,” *J. Eng. Educ.*, vol. 94, no. 1, pp. 147–164, 2005, doi: 10.1002/j.2168-9830.2005.tb00835.x.