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WIP: Arduino-Based PBL to Foster Entrepreneurial Mindset

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Abstract

This work-in-progress paper examines a semester-long project-based learning initiative begun in an introductory engineering course during the Fall 2025 semester. The project aims to enhance students' hands-on experience by integrating information literacy, the engineering design process (EDP), and an entrepreneurial mindset (EM) [1]. The objective is to boost student confidence in teamwork, technical problem-solving, and application of skills, preparing them for future courses in their discipline. Students in this introduction to engineering course received an Arduino Uno R3 Controller board kit and additional sensors. They were tasked to develop a device addressing engineering in the medicine challenge of their choosing. Teams are formed using Gruepr [2] software, and subsequently a team policy agreement was created with members of each group. Research questions were formulated by each team that were geared toward exploring topics related to engineering in medicine. These research questions were evaluated using literature to identify gaps and to assess the relevance of their research topic to real-world issues. This educational intervention led students to further improve their research skills, in the first half of the project, and in the second half, they further explored their making skills through the use of a makerspace to construct a prototype. They were simultaneously introduced to Arduino hardware and software through tutorials and online resources. The course culminates in technical reports and presentations demonstrating their application of the EDP and EM. This paper evaluates the feasibility and design of this course, with future plans to conduct a formal human subject's study, pending IRB approval, to assess student self-efficacy through survey responses.

Introduction

Project-based learning (PBL) has been shown to be an effective method for engaging undergraduate students in introductory engineering and technology courses [3–5]. Among recent prototyping technologies available to students and maker communities, the Arduino electronic prototyping platform stands out as an open-source system designed for ease of use [5]. Developed at the Interaction Design Institute Ivrea, Arduino was created to bridge the gap between artists and engineers by enabling interactive installations without requiring advanced electronics knowledge [6].

Arduino’s low cost, open-source ecosystem, and approachable learning curve make it highly accessible to first-year students in both in-person and online settings. Integrating Arduino as a PBL component in a freshman engineering course provides an effective bridge between theory and hands-on application [7, 8]. Through this approach, students gain experience with essential instrumentation and data-processing tools involving hardware, interfacing, sensors, and coding. They also reinforce concepts from their introductory programming course, which they typically take during the freshman year.

Students develop confidence through the immediate, tangible outcomes of their prototyping work. They engage in collaborative roles that require them to define engineering problems, design and test prototypes, communicate results to appropriate audiences, and apply problem solving, data analysis, and design thinking in meaningful real-world contexts. The biomedical emphasis of this project also aligns with the college's broader goals of integrating engineering and medicine, which is especially relevant given the institution's recent merger with the Eastern Virginia Medical School (EVMS).

Old Dominion University holds a unique position within the Hampton Roads region of Virginia due to its proximity to major industries, including aerospace research, military installations, shipbuilding, international deep-water port facilities, and a nationally recognized nuclear physics research center. The engineering and engineering technology programs intentionally leverage these regional assets throughout their curriculum. The freshman Introduction to Engineering and Technology course, which is required for all majors in the Frank Batten College of Engineering and Technology, features team-based projects that introduce students to themes related to these industries. These themes include maritime, aerospace, sustainability, environmental engineering, and engineering in medicine.

The primary objective of these projects is to support course goals focused on developing students' problem-solving abilities while fostering key professional skills such as teamwork, collaboration, project management, communication, and information literacy. Recent course revisions place additional emphasis on strengthening student self-efficacy, specifically motivation, effort, and persistence, through the integration of an EM within a biomedical-themed Arduino project.

This approach is supported by the Engineering Unleashed community [9] and the KEEN network, which is funded by the Kern Entrepreneurial Engineering Network [10]. These initiatives promote the 3Cs framework of Curiosity, Connections, and Creating Value [8–10] and encourage the integration of EM principles within undergraduate engineering courses. The network provides professional development opportunities through workshops and an extensive online repository of projects and activities that can be integrated into existing curricula. Faculty involved in these efforts share ideas and resources to help prepare students for careers that require innovation and practical engineering skills.

Intro to Engineering and Technology Course Structure

Our college has five different departments with four different undergraduate engineering sciences degrees: mechanical engineering, electrical engineering, computer engineering, and civil engineering; and four different majors under engineering technology degree: civil engineering technology, electrical engineering technology, manufacturing engineering technology, and mechanical engineering technology. All freshman students in our college are required to take the Introduction to Engineering and Technology course.

Introduction to Engineering and Technology is a four credit-hour course consisting of two team-taught 75-minute lectures each week and 110-minute laboratory session led by a single instructor. This course was offered in both in-person and online modalities, with the online section following the same structure as on campus, except entirely taught by a single instructor.

Each instructor leads a project theme, which varies by section; examples include maritime engineering through small-scale boat-building, renewable energy through wind-turbine blade design for maximizing power output, and other hands-on engineering challenges. These themes provide freshman students with practical exposure to core engineering principles.

The lecture covers core content areas summarized in Table 1, while the laboratory provides hands-on reinforcement of some of the topics, though not necessarily aligned with the lecture topic covered in the same week, through project-based activities. All five instructors who are teaching this course are working together with their director to make sure that content is designed in a way that satisfy all different degree programs and their ABET requirements. The course was completely redesigned in academic year 2022-23 when it was transformed into a four-credit course, the first one in the freshmen introduction to engineering and technology sequence.

The course includes hands-on activities involving embedded systems, programming, interfacing, and electronics components, as well as integrated learning activities related to engineering design, research, and engineering practice. Students learn coding and design skills while being introduced to different engineering majors and core engineering competencies. A detailed course schedule is provided in Appendix A, Table 1.

The course begins with the Introduction and Foundations module, which spans the first two weeks. This portion covers engineering basics, student success skills, technical writing, and documentation practices. Students are introduced to the engineering design process, information literacy, engineering research methods, library resources, and professional databases. An overview of weekly topics appears in Appendix A, Table 1.

In the third week, students transition to the Research, Standards, and Project Planning module. This module emphasizes interpreting datasheets and understanding engineering standards across various disciplines. Students are also introduced to the physical components of the project-based course through the Arduino-based biomedical device project. During this stage, they learn teamwork skills, team policies, safety protocols, and structured project planning. See Appendix A, Table 1 for the weekly sequence.

The Data, Tools, and Technical Skills module (Weeks 4 through 6) covers engineering data types, unit conversions, decision making strategies, and problem-solving methodologies. This section culminates in hands-on work with Arduino platforms, simulation tools, Excel-based exercises, and exploration of the hardware provided in Arduino UNO starter kits. This module is particularly valuable for online students who do not have access to campus laboratories, as Arduino UNO kits are affordable and widely available for remote prototyping. The detailed outline is shown in Appendix A, Table 1.

The Design, Fabrication, and Analysis module (Weeks 7 through 9) focuses on advanced problem solving, planning for the fabrication stage, engineering efficiency calculations, data analysis, and engineering graphical communication. This section concludes with project checkpoints and development of the technical report. Refer to Appendix A, Table 1.

Biomedical-Themed Arduino Project

In the first weeks of the semester, students received an Arduino Uno Kit, specifically the Elegoo Super Starter Kit [11], which included a 16x2 character LCD display [12], a sensor breadboard, an Arduino shield, and a 5V battery connector. Students were also given a Comimark heart rate pulse sensor module with header pins and three female to male jumper wires, which required soldering before it could be used properly. In addition, each student received a WWZMDiB DS18B20 Temperature Sensor Probe High Accuracy Waterproof sensor [13] along with a 4.7 kΩ resistor [14]. These materials were provided to give students the opportunity to explore, experiment, and engage in early hands-on discovery within the course.

Students completed a survey through Canvas LMS, which collected information on gender identity, race and ethnicity, prior experience with biomedical devices and instrumentation, major, preferred team role, academic year, availability, and preferences regarding potential teammates. These responses were used to form project teams through the Gruepr software. Students were also provided with a team policies agreement template that prompted them to describe their preferences for communication, decision making, group assessment, submission practices, and meeting and facilitation approaches. This template later supported group discussions as teams developed their collective team policy.

To prepare for an upcoming library visit, students watched a short introductory video on library resources and their application to research activities. This assignment, along with a series of self-paced information literacy tutorial modules across three weeks marked the start to building of foundational understanding of the information research process for students.

Students were provided with a project overview handout that explained the biomedical engineering focus of the assignment, with a more specific emphasis on biomedical devices and instrumentation. It informed them that they were tasked with researching and developing a device based on a biomechanics-related research question of their choice. For this project, students had to integrate the provided Arduino, Arduino shield, LCD display, temperature sensor, and heart rate pulse sensor into the final biomedical data collection device. The project outline specified that students would follow the engineering design process and that the final deliverables, with rubrics included, consisted of an individual technical report and a group presentation. The technical report required each student to apply the information literacy skills learned in class to research the background of the chosen question and to analyze and present the results. The group presentation required students to demonstrate how they followed the engineering design process, tested their device, and analyzed the collected data. Guidelines and structural expectations were provided in the document.

Students were given a preliminary research question builder worksheet structured around the EM 3Cs: curiosity, connections, and creating value. They began by identifying biomechanics or human performance topics they were curious about. They then established connections by reviewing journal articles to determine what was already known and where gaps existed in the literature. Finally, they considered how their question could create value by determining its relevance to real problems, performance improvement, or risk reduction, and whether Arduino sensors could provide adequate data. These steps prepared students for database searching using keywords drawn from their research question. This activity was completed during an instructional session with the Engineering and Physical Sciences Liaison Librarian, who guided them in refining searches using university resources and publicly accessible platforms such as Google Scholar and PubMed.

In subsequent weeks, students completed safety training modules, including general laboratory safety, filament 3D printing, resin 3D printing, and laser cutter and engraver training, along with associated quizzes. These modules prepared them to create prototypes in the campus makerspace, or at minimum provided the background necessary to use off-campus makerspace facilities or personal tools. The following week, students completed a group research project planning worksheet. This worksheet helped teams outline their plan of action for coding, prototyping, data collection, and technical writing. They identified the theme of their project, articulated limitations such as available materials, sensor capabilities, and team skills, and refined their draft research question to ensure that it was testable and focused. Students also reviewed online materials and instructional videos focused on Arduino programming essentials, navigation of the Arduino IDE, and virtual prototyping in Tinkercad.

In the next phase, students completed a worksheet organized again around the EM 3Cs. They researched existing biomedical devices for inspiration, measured and sketched their components, and made connections by comparing design features, casing shapes, sensor placement, and how the devices related to their research question. To create value, they generated multiple casing and layout design sketches and used a weighted benefit analysis to justify their final selected design. As instructional guidance decreased in subsequent weeks, students completed a fabrication planning worksheet. They identified required materials and components, determined necessary tools, and reviewed their case design to ensure access to ports such as the USB connection. They also created a fabrication timeline and checklist verifying material acquisition, tool readiness, finalized design, fabrication progress, and device testing. The worksheet included reflection prompts linked to the 3Cs, such as Curiosity (what questions guided the design process and what new insights emerged), Connections (how the project related to other disciplines or real-world problems and who might benefit from the solution), and Creating Value (what value the design provided and how it could be improved or scaled). Students were provided with reference resources on assembling and coding the 16x2 LCD, pulse sensor, and temperature sensor, as well as examples of combining code for multiple components.

At mid-semester, students completed a group checkpoint worksheet where they explained their code step by step using algorithmic descriptions, showed visible prototype progress, and demonstrated initial data collection and analysis. In the following week, students received instruction on IEEE technical writing and worked through a guided worksheet that helped them develop their introduction and background sections.

In the second-to-last week of class, students submitted their individual technical reports, and in the final week they delivered group presentations that drew heavily on the content and structure developed in their reports. This complete sequence of instructional activities and milestones appear in Appendix A, Table 1. Figures 1–3 illustrate components of an exemplar student team's final project, highlighting the iterative application of both EDP and EM. As shown in Figure 1, the team engaged in benchmarking and brainstorming to define and refine their design approach. Figure 2 documents subsequent ideation, revision, fabrication, and assembly of the device casing and internal components that house the Arduino and auxiliary hardware and sensors. These iterative steps culminated in the implementation of a successful final prototype as seen in Figure 3, demonstrating the integration of technical design, problem solving, and value-driven decision making.

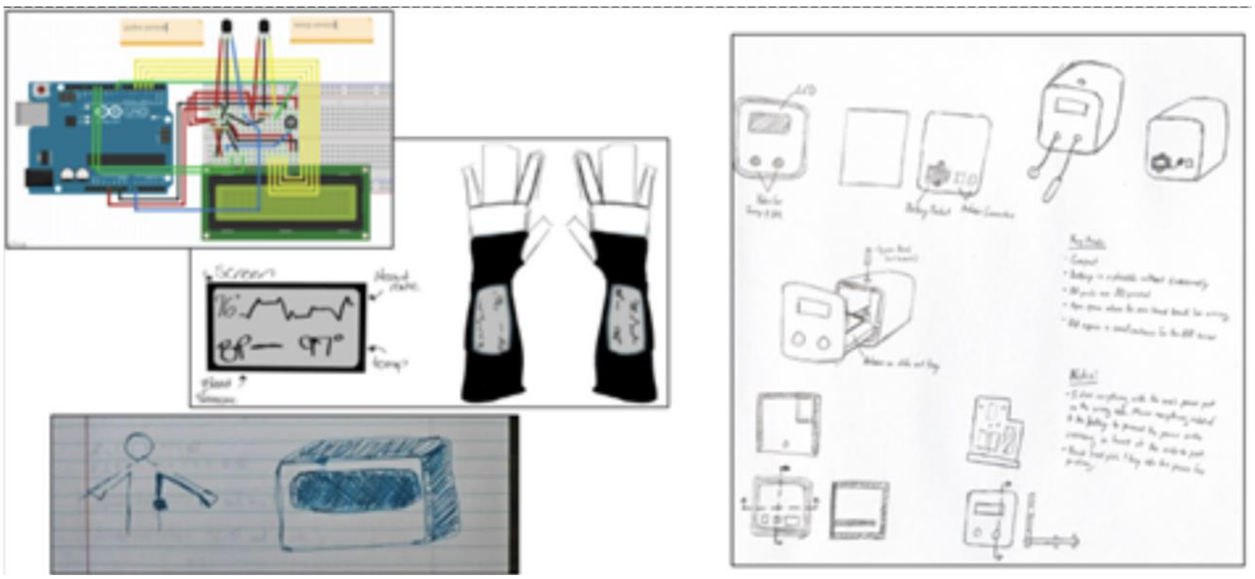

Figure 1: Student brainstorming & benchmarking – sketching and schematic

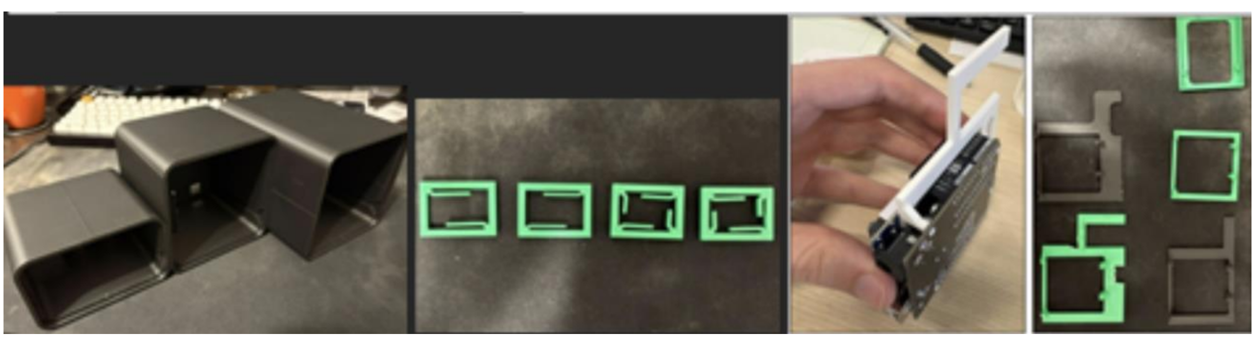

Figure 2: Biomedical device parts fabrication and assembly to Arduino UNO

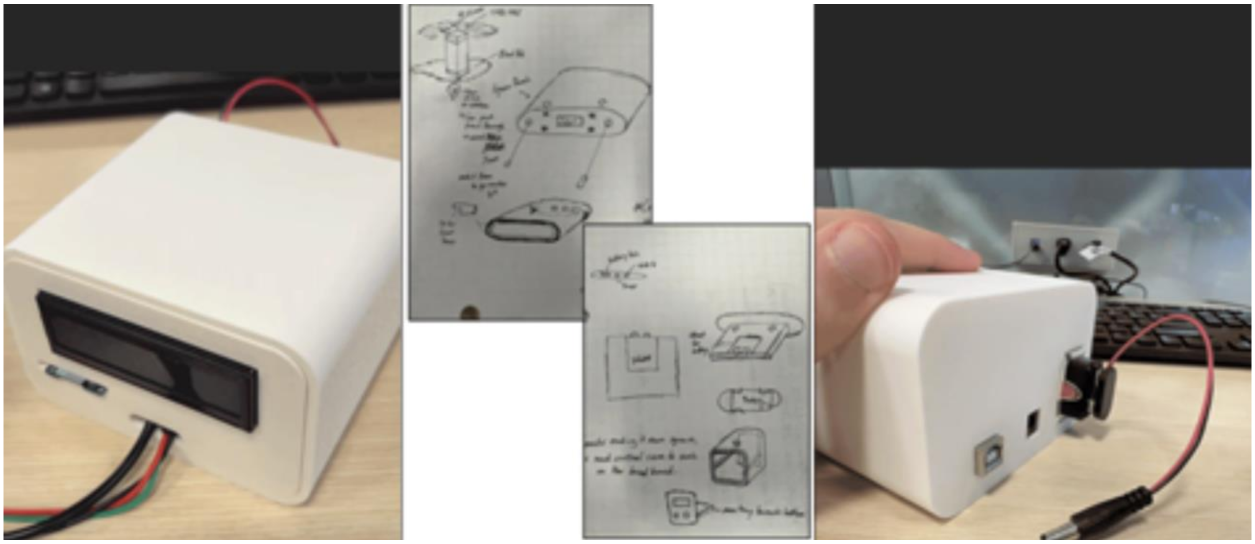

Figure 3: Biomedical device housing prototype and initial design sketches

Resources

A “Card” serving as an information repository has been created for this work on the Engineering Unleashed platform. This card (Arduino-Based PBL to Foster Entrepreneurial Mindset, Card #5232) contains the instructional materials referenced in this paper, including project descriptions, worksheets, rubrics, and supporting resources used in the course project. These materials are available for review, adoption, and adaptation by other instructors through the Engineering Unleashed website. The project design builds on prior work that introduced Arduino kits into introductory engineering courses, providing historical context and pedagogical grounding for the current implementation. These materials can be freely downloaded, reviewed, adopted, and if desired, modified by anyone for use in their courses under the Creative Commons CC BY-NC license.

Conclusion

Preliminary results from this work-in-progress suggest that integrating an Arduino-based, biomedical-themed project grounded in an EM framework is both feasible and effective for a first-year introduction to engineering course. Informal student feedback indicated that, while the project was challenging, it was perceived as meaningful and valuable, as students developed teamwork skills, research abilities, and hands-on technical knowledge largely through self-directed effort. From the instructor’s perspective, student teams produced stronger final designs and more cohesive prototypes than in previous offerings of the course, which is likely attributed to the structured integration of the EM 3Cs throughout the project. While these outcomes are encouraging, opportunities for improvement remain, including greater involvement of stakeholders to help guide student design decisions, improved clarity and pacing of assignments, increased hands-on instruction in coding and hardware integration, and potential adaptation of project components to improve quality of data collected while accommodating budget constraints. Future work will focus on refining the course design and pursuing formal assessment of student self-efficacy and learning outcomes pending IRB approval.

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[13] DS18B20 1-Wire Digital Temperature Sensor, Maxim Integrated (Analog Devices) datasheet, 2016.

[14] 4.7 kΩ resistor, ±5 % tolerance, through-hole carbon film resistor, manufacturer datasheet, 2024.

Appendix A

Table 1. Representative schedule of instructional lecture topics and lab project components.

Week	Lecture	Labs
Week 1	Introduction (Overview; engineering basics; study skills; documentation; technology; problem-solving; engineering design process; engineering vs. engineering technology)	Arduino Kit & Sensor Distribution; Group Project Survey; Introduction to the Library Video; Information Literacy Tutorials; Team Policies Agreement (Individual Input)
Week 2	Engineering Design Process, Information Research Process Code of Ethics,	Preliminary Research Question Builder Worksheet; Information Literacy Tutorials
Week 3	Datasheets and Standards	Arduino-Based Biomedical Device Project – Project Overview, Technical Report Guidelines/Structure & Rubric, PowerPoint Presentation Structure & Rubric; Team Policies Agreement (Group Input); Group Research Project Planning worksheet; Makerspace Safety & Tool Training Modules; Information Literacy Tutorials
Week 4	Types of Data Dimensions and Units Unit Conversions	VIDEO: Programming Electronics Academy: Arduino MASTERCLASS | Full Programming Workshop in 90 Minutes; Arduino MASTERCLASS Quiz; Arduino IDE, Autodesk Tinkercad; Excel Challenge
Week 5	Reasonableness and Decision Making	Biomedical Arduino Device Design Worksheet; Excel Challenge
Week 6	Problem Solving	Elegoo: Super Starter Kit UNO R3 Project - CD Content; Excel Challenge
Week 7	Problem Solving Continued	Fabrication Planning Worksheet; Project Resources (LCD, Pulse Sensor; Temperature Sensor, Combining Arduino sketches); Excel Challenge
Week 8	Calculating Efficiency	Group Checkpoint - Algorithm Flowchart, Prototype Progress & Data Testing; Excel Challenge
Week 9	Graphical Communication	Technical Report Writing Worksheet
Week 10	Uncertainty	
Week 11	Design for All	
Week 12	PE Licensure	Technical Report (Individual Submission)
Week 13		Group Presentation