Introducing a Research Project to a First-year Mechanical Laboratory Course

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Introduction

The first year of an engineering program typically serves as an introduction to fundamental engineering concepts and principles, with laboratory work playing a crucial role in this educational process. The significance of laboratories in providing students with hands-on experiences that complement theoretical learning has been explored in [1]. These first-year engineering labs can effectively acquaint students with the captivating and demanding field of engineering, while also preparing them for further studies and careers in the discipline.

As part of the first-year engineering curriculum, a Mechanical Engineering Laboratory course was developed and offered in the Fall of 2022. This course aims to cultivate fundamental technical skills and exposure through a series of practical laboratory sessions. It is a 2-credit course consisting of a 1-hour lecture and a 2-hour lab session each week. The course introduces students to various concepts including laboratory safety, experimental design, measurement techniques, design synthesis, computer-aided design (CAD), algorithmic thinking, simulation, and technical reporting. The objective is to equip students with practical knowledge in utilizing and applying modern engineering tools and techniques necessary for engineering practice through hands-on laboratory experiments. To achieve this objective, students are required to undertake a research project where they read a technical paper and replicate a portion of the work using the tools they have learned in the course.

There is existing literature that explores the incorporation of published primary/technical papers into undergraduate education across various disciplines [2]~[6], and all have shown positive impacts on student learning. Grindle et al. [3] conducted a study to test the effectiveness of engaging first-year students with research papers. In their research, first-year, first-term undergraduate students were exposed to current research in probability and statistics by reading a research paper and summarizing it for a general readership after conducting an interview with the paper's author. Kershaw et al. [4] implemented deliberate and distributed practice through a series of structured assignments to enhance students' abilities in identifying key research concepts and summarizing complex ideas from published research articles for undergraduate psychology majors. Kulkarni and Vartack [5] developed a three-day module, conducted outside the classroom, to introduce first-year students to critical reading of primary literature in biology. In our case, our focus lies in utilizing modern tools to reproduce parts of the results from research papers, providing students with experiences on how to apply them in practical applications and fostering a deeper understanding of the concepts. This paper describes the implementation of the research project in detail. The challenges faced and the feedback from students are reported, and some suggestions to improve the course are also addressed.

Implementation of Research Project

In the laboratory course, students were introduced to various engineering tools, including SolidWorks 3D modeling, Excel, and LabVIEW for data acquisition. Once students gained familiarity with these modern tools, they were assigned a research project. The project required

them to read technical papers and implement a part of the work presented using the tools they had learned in the course. This could involve tasks such as building a 3D model with SolidWorks, programming with LabVIEW, performing calculations in Excel, and more. For the research project, students were required to work in groups and complete the assignment within a three-week timeframe. They were also expected to write a report reviewing the technical paper and present their findings in class.

Reviewing technical papers offers several benefits to students: keep up with the latest research and advancements in their field of study; gain valuable insights into research methodologies, experimental designs, and data analysis techniques used in the mechanical engineering field. However, it can be challenging for first-year students to read highly advanced technical papers that require additional background knowledge. To address this limitation, we carefully selected the technical papers. Following the five core technologies identified by ASME: Manufacturing, Pressure Technology, Clean Energy, Bioengineering, and Robotics [7], we recommended technical papers in these areas to the students. The topics included additive manufacturing, robotics in manufacturing, artificial intelligence and machine learning in the design of mechanical materials, electric vehicles, Internet of Things, renewable energy, and smart manufacturing system design based on digital twin technology in Industry 4.0. However, students also had the option to choose a different technical paper of their own interest. Reproducing the work presented in the technical papers poses another challenge for the students. Since they have only been exposed to the modern tools during the course, completing certain aspects of the project requires them to delve deeper into self-directed learning. Students may need to conduct more research, seek out online resources, consult textbooks or manuals. This process of learning is beneficial for the students as it helps develop their lifelong learning skills.

Sample Project and Student Feedback

The research project generated significant enthusiasm among the students, who eagerly undertook various projects. Here are a few sample projects that students pursued:

- Exploring 3D Printing: A team of students delved into the realm of rapid prototyping methods, specifically focusing on 3D printing. They utilized SolidWorks to design a cup, as depicted in Figure 1. Subsequently, they had the opportunity to bring their design to life by utilizing the maker space on campus to print the cup.
- Hydropower Turbine Design: Another student team dedicated their research project to studying hydropower turbines. They conducted a comprehensive review of different turbine types and, utilizing SolidWorks, designed their own turbine shown in Figure 2.
- Car Transmission System Analysis: A separate student team undertook an investigation of a car transmission system. They developed a LabVIEW program that facilitated the calculation of the car's RPM output based on the gear ratio as shown in Figure 3.

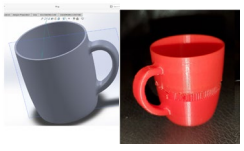

Figure 1. 3D model of a cup and the 3D printed cup.

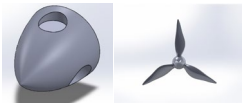

Figure 2. Hydropower turbine 3D model

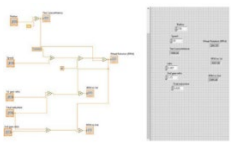

Figure 3. RPM Calculator in LabVIEW

An evaluation was sent to the students after they completed the course. There were 21 students who participated in the evaluation. Although the feedback pool was relatively small, it reflected the overall feedback from the students. When asked about the research project, 90% of the students enjoyed it.

Conclusion and Future Work

Overall, the research project was successfully implemented, over 90% of students enjoyed the research project, which allows them to explore subjects they were interested in and exposed them to real-world problems, research methodologies, and the latest advancement of the professional field. They also experienced the application of the tools learned in class. As a future step, it is essential to develop an assessment plan to evaluate the effectiveness of the research project. To address the challenge that first-year students face in reading technical papers, providing additional guidance and support is crucial. Here are some suggestions to enhance the guidance for students: i) Research Questions: Provide students with a set of research questions that help guide their reading and comprehension of the technical papers, as described in [2]. These questions could focus on identifying the main research objectives, hypotheses, experimental setup, data collected, results, and suggestions for future research. This approach assists students in extracting key information and gaining a deeper understanding of the paper; ii) Collaborate with an English literature class or integrate reading strategies into the curriculum to provide students the guidance on how to approach technical papers, extract relevant information, and effectively summarize the main findings; iii) The project could be extended to 7 weeks to give more time for students to get deeper knowledge about the field.

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