Application of Extracurricular Course Teaching PLM Concepts to Undergraduates

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Overview

- Reviewing an undergraduate research project helping teach PLM

- Position paper on efforts to teach engineering undergraduates about PLM

- Discuss practices, observations, and future work

- Conducted over 4 semesters: Fall 2021 through Spring 2023

Undergraduate engineering students engaged in research for the PLM course

Product Lifecycle Management (PLM)

- The tools and processes used to manage a product's information throughout the product lifecycle
- Includes topics such as:
  - Product Data Management (PDM) and Database management
  - CAx tools
  - Digital thread
  - Digital twins
- Critical to Industry 4.0
- Need for PLM to be taught to engineers[1]
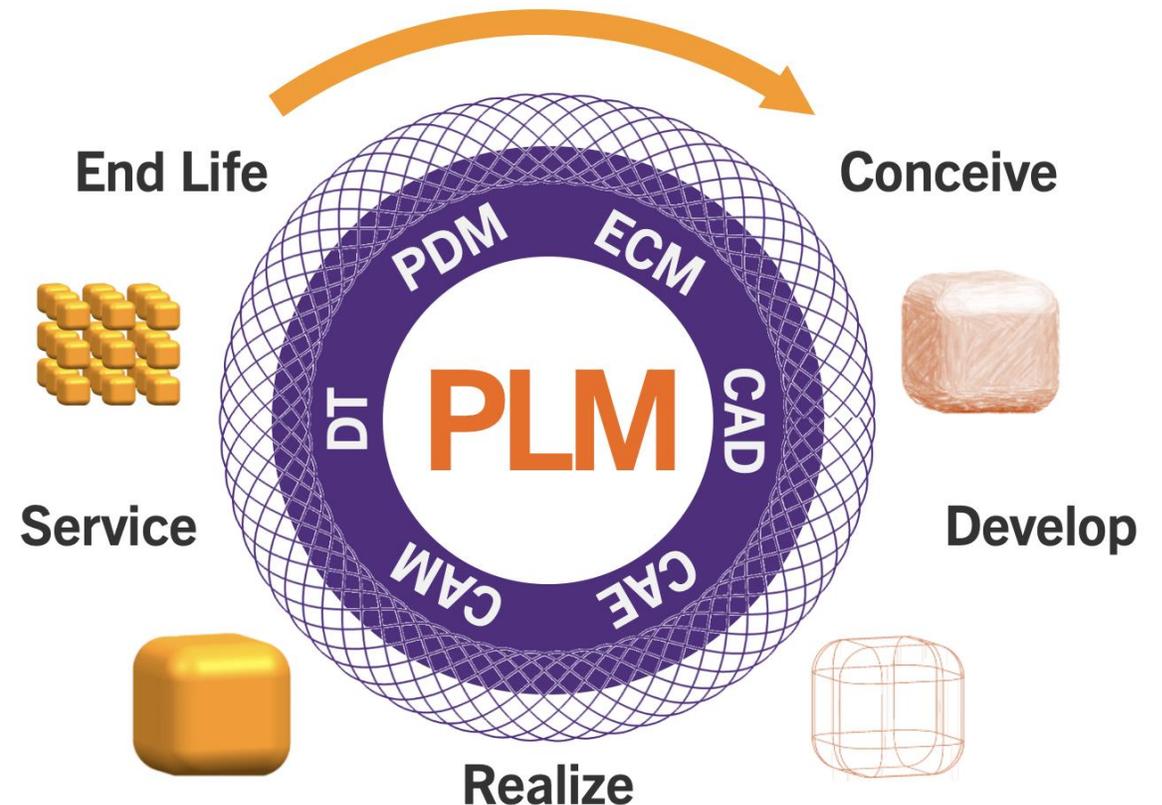
1. CIMdata, "Need For a 21st Century Engineering Curriculum," CIMdata Commentary, Feb. 26, 2019.

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Problem

- 5 highest curriculums by credit hour are all engineering programs[1]

- High credit-hour programs make it difficult to make new classes

- 3 universities offering explicit PLM courses (including Purdue University)[2]

- Subjects that include PLM as sub-topic:
  - Computer Aided Manufacturing
  - Engineering Database Development
  - Distribution and Logistics Management
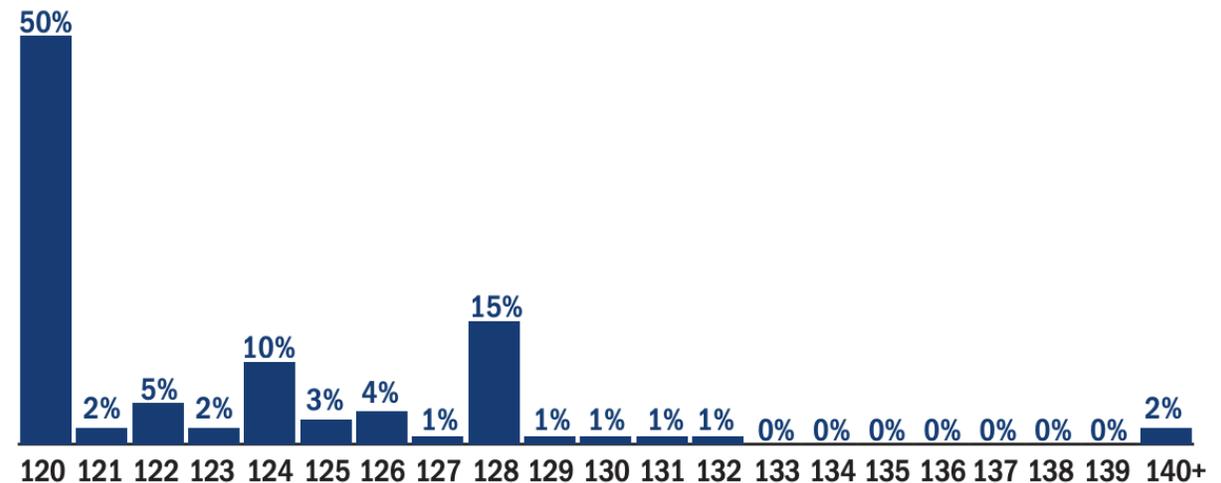
Bachelor's degree credit-hour program requirements for over 500 universities in the United States
*Figure from [1]*

1. N. Johnson, L. Reidy, M. Droll, and R. E. LeMon, "Program Requirements for Associate's and Bachelor's Degrees: A National Survey," Complete College America, Washington DC, Jun. 2012.
2. Based off course catalogs maintained by CollegeTransfer.Net, as of May 2023

Teaching PLM

Difficulties

- Requires expansive breadth of technical skill using digital tools

- Builds upon product design and product development baselines

- Multidisciplinary: includes manufacturing, engineering, business and other disciplines
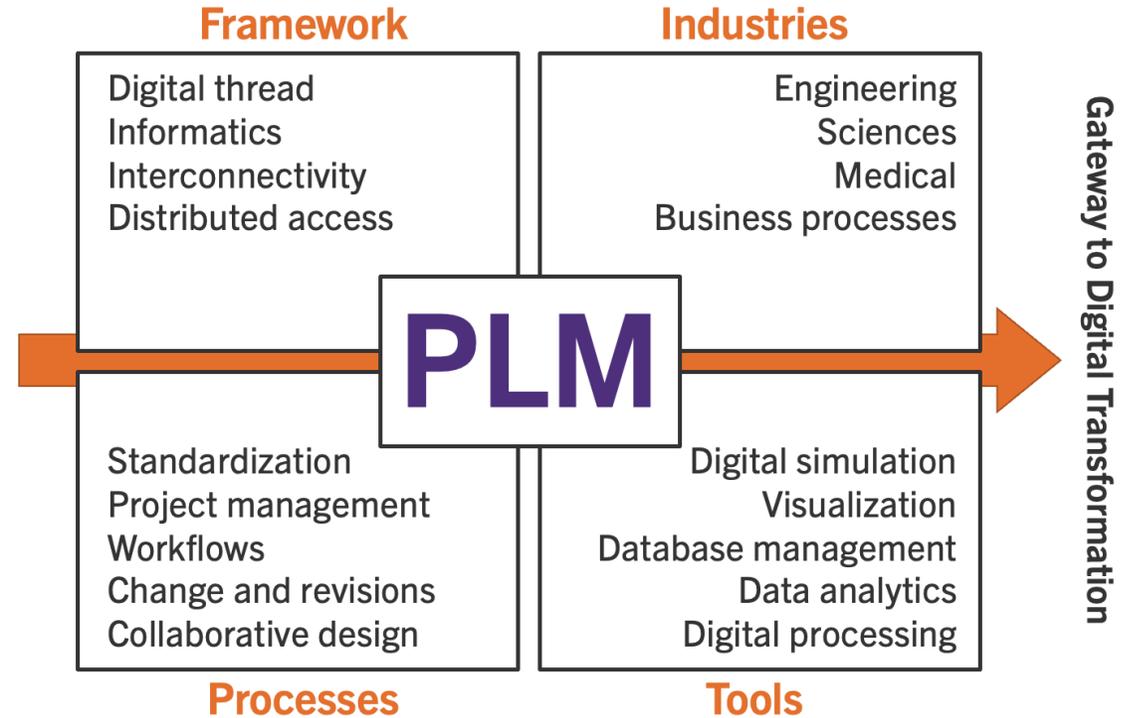
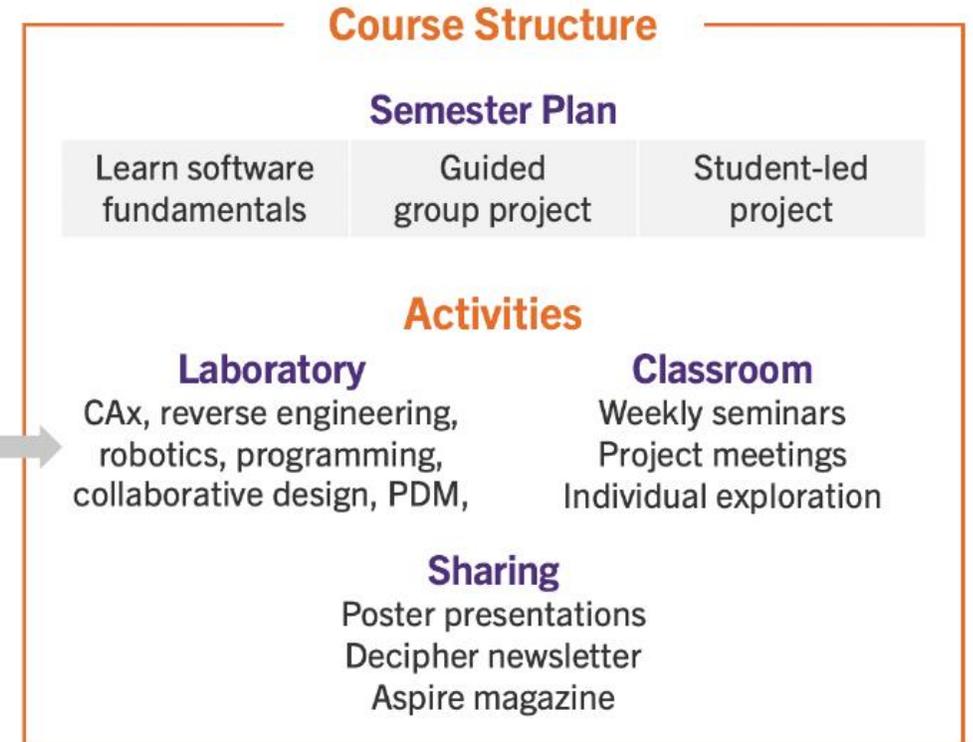
Components and Usage of PLM

Course Overview

Approach

- Extracurricular research project for 1 credit hour
- 4 to 9 students per semester

2 parts:

- Training:
  - Classroom lectures
  - Software training
- Research
  - Group meetings
  - Group projects
  - Student-led projects

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Software
Siemens NX
Siemens Teamcenter
Arduino

Course Structure

Semester Plan

Learn software fundamentals	Guided group project	Student-led project

Activities

Laboratory
CAx, reverse engineering, robotics, programming, collaborative design, PDM,

Classroom
Weekly seminars
Project meetings
Individual exploration

Sharing
Poster presentations
Decipher newsletter
Aspire magazine

Overview of extracurricular course

Course Breakdown: Seminars

- Each student was required to attend weekly, 1-hour seminars hosted by the Product Lifecycle Management Center at Clemson University (PLMC)

- After each seminar, the class participated in a group discussion about the topics learned

- Seminars available asynchronously

Fundamental Concepts
- 1.1 Introduction to Product Lifecycle
- 1.2 Digital Components of PLM
- 1.3 PLM Functional Areas
- 1.4 PLM in Practice

Digital Product Development
- 2.1 Product Design Tools and Approaches
- 2.2 Data Preservation and Security
- 2.3 Additive Manufacturing
- 2.4 Data Analytics and Mining

Graphical Concepts
- 3.1 Computer Aided Design Methods (CAD)
- 3.2 Computer Aided Engineering (CAE)
- 3.3 2D Drawings and GD&T
- 3.4 System Simulation and Optimization

Non-graphical Concepts
- 4.1 Project Management
- 4.2 Product Data Management
- 4.3 Engineering Change Management
- 4.4 Systems Engineering and MBE

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Research Objective

- Create a Digital Twin of a robotic, differential drive vehicle

- Digital Twin is a high fidelity, virtual representation of a real-world entity that mirrors the state of the entity through some sort of synchronization

- Requires complex modeling and information management

Physical Asset

Virtual Representation

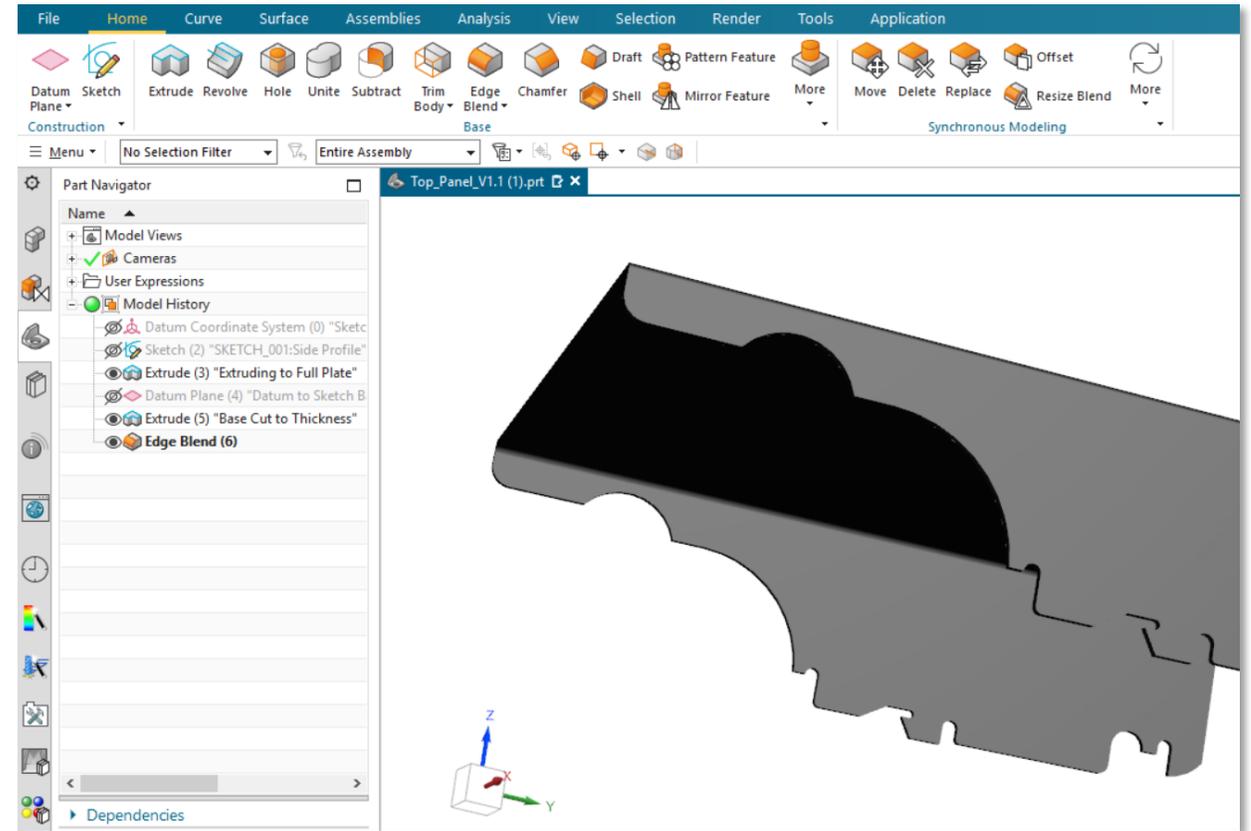**Synchronization**

Data
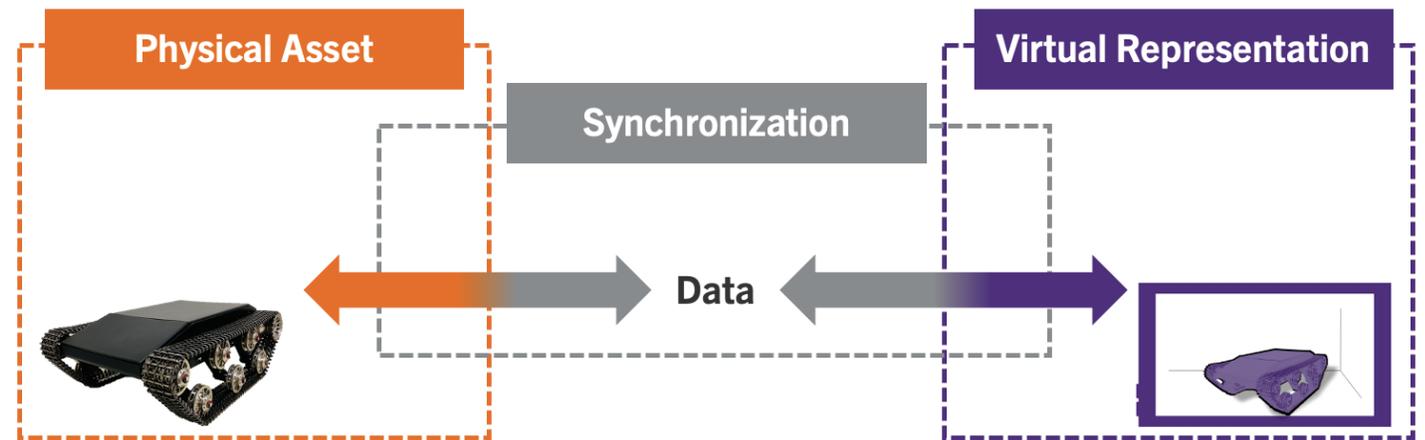
Servicing and Maintenance

Four parts of a Digital twin

Course Breakdown: Technical Training

- Self-guided modules taught the basics of Siemens NX

- Modules mapped with relevant research projects, such as reverse engineering the geometry of the robot

Part modeling of robotic vehicle in Siemens NX

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Course Breakdown: Group Projects

- Students were grouped in teams of <4 to do an abbreviated design project

- Encourage collaborative design principles, as well as organizational data management

- Students take on roles of designers, product managers, and system engineers

Prototype odometer shown on vehicle tread

Course Breakdown: Group Meetings

- Group meetings were used to
  - Discuss progress
  - Perform design reviews
  - Discuss recent seminar
  - Coordinate on projects
  - Demonstrate new topics

- Meetings included workshops teaching CAD (Siemens NX) and PDM (Teamcenter)
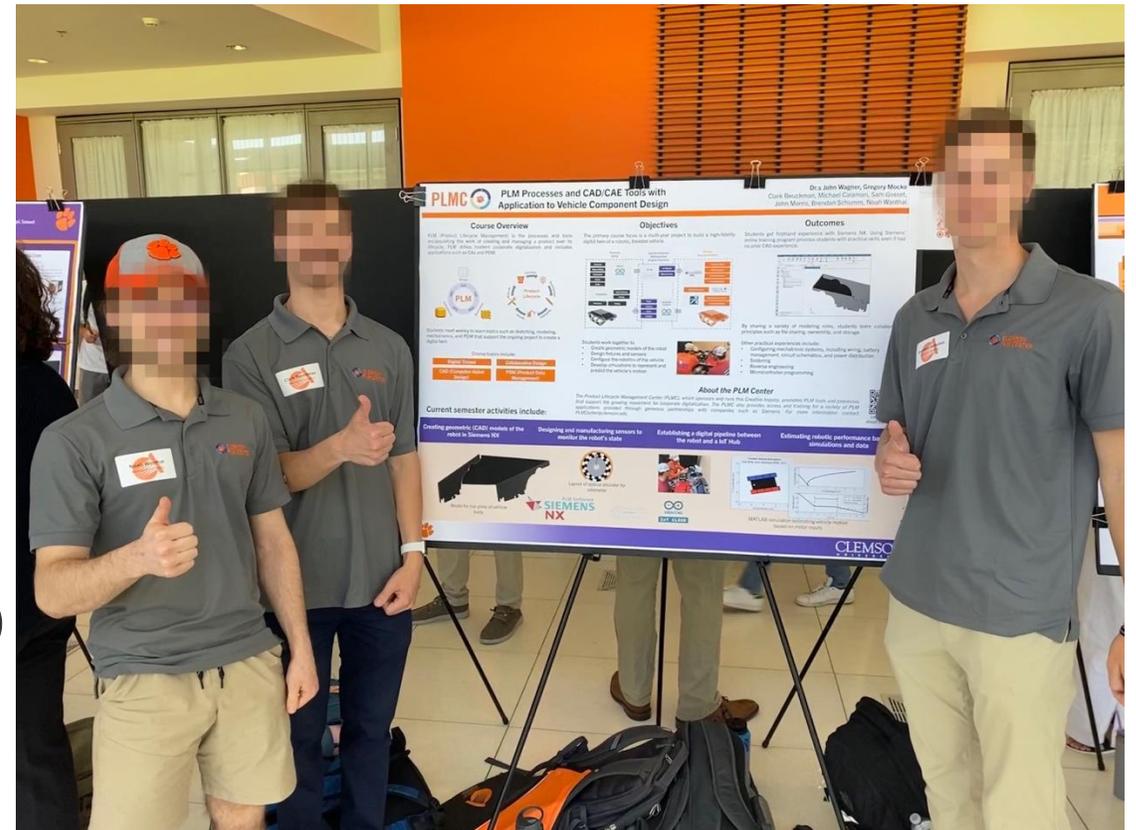
Students present research in poster forum in April 2022

Course Breakdown: Student-led Projects

- After group project, students choose their own project to work on

- Projects must contribute to the overall objective of establishing a digital twin

- Allows students to pursue topics of interest to themselves

Differential Drive Simulation
Port RPM: 0.00 Starboard RPM: 0.00
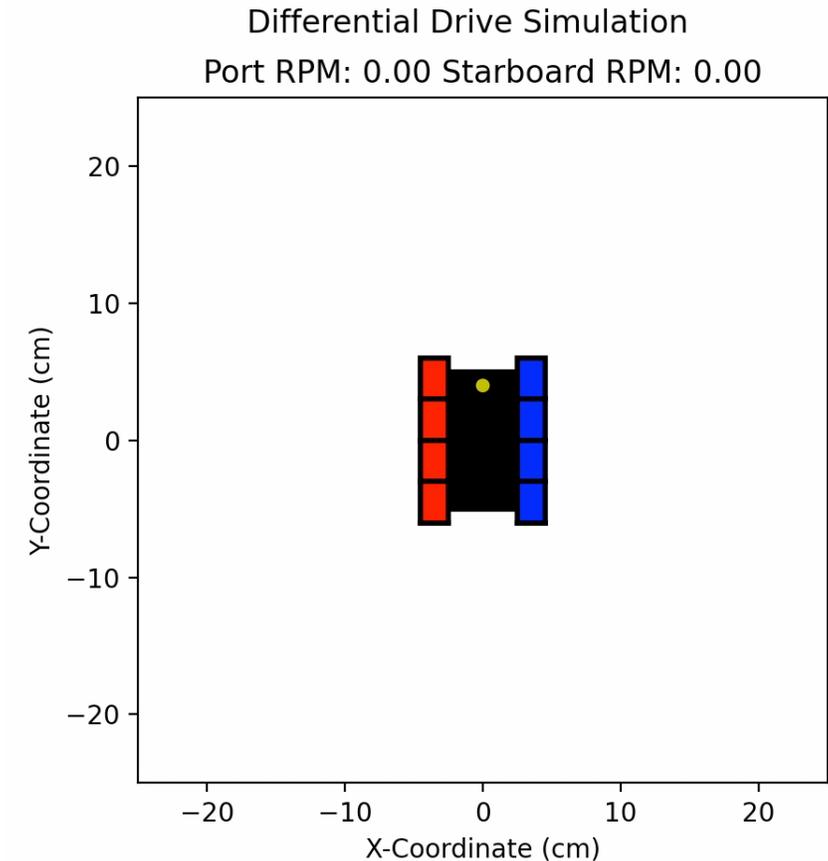
Programmed simulation of vehicle motion prepared with aid from student participants

Observations

Project Relevancy

- Diversity of experiences provided by DT allows highly applied learning opportunities

Scalability

- Reach of a single session is limited to less than 10 students per semester
- Project can be scaled using distributed sections with centralized lecturer
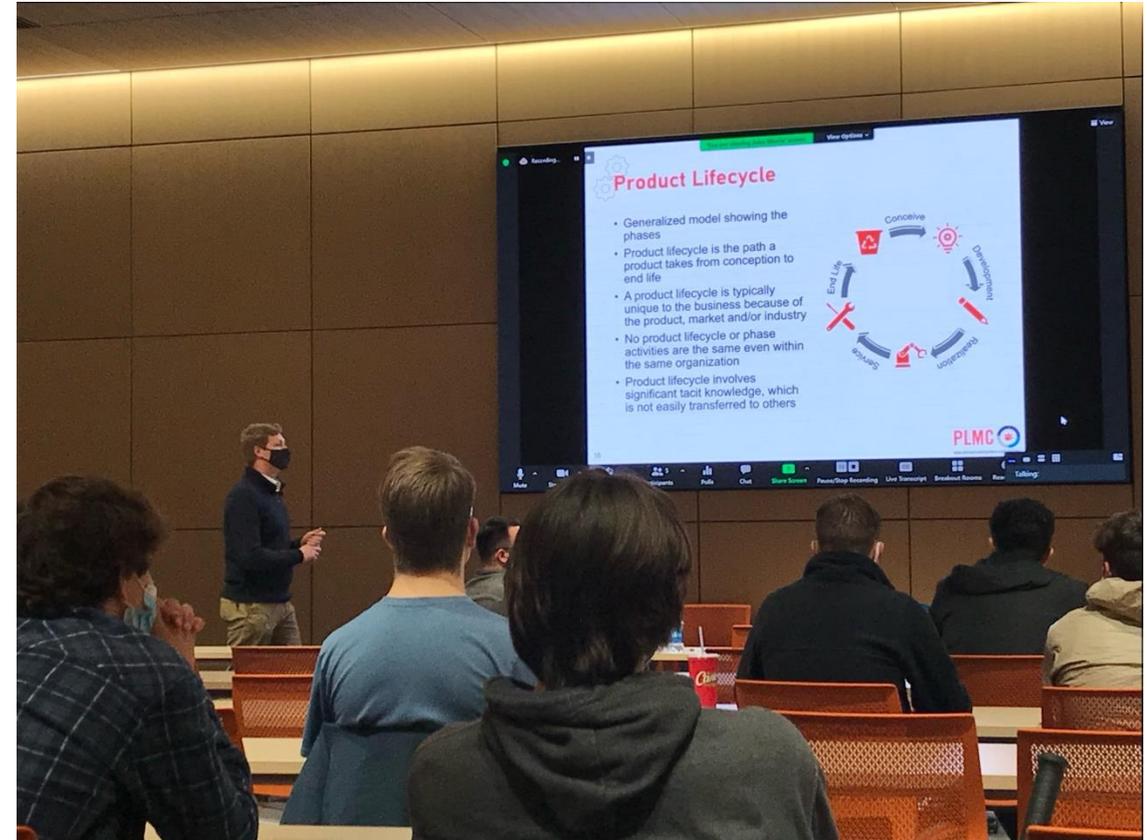
Course can be scaled using distributed sections

Future Work

Concerns

- Ability to continue giving introductory experiences that are relevant to the overall project
- Chance for students to do self-guided learning

Future work

- Gather data on effectiveness of course versus fully-established course
- Introduce organizational roles to the students

Instructing on PLM concepts to undergraduate engineering students in Spring 2022

Questions

This research was conducted through the Product Lifecycle Management Center at Clemson University.

More information on the center can be found at https://www.clemson.edu/centers-institutes/plm/