

Teaching Introductory Mechanical Design Using a Continuous Prototyping Mindset

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Overview and Objectives

The objective of this project is to **engender a continuous prototyping mindset** in students so that they may be introduced to mechanical design **through authentic, iterative, inquiry-guided project experiences**.

I define a prototype as *an interactive experiment intended to gather information for further learning*. The prototyping mindset is an inquiry-driven approach that encourages students to **identify missing information and anticipate unknowns, ask appropriate questions, perform an experiment** (create a prototype) proactively, and **iterate** in order to continually improve their design decisions.

Outcomes

- Design and conduct tabletop experiments
- Interpret experimental data
- Identify and apply appropriate techniques, skills, and engineering tools to solve mechanical design problems
- Use the continuous prototyping mindset to enable reflection and lifelong learning

Developmental History

Aspects of the project have been implemented on an ad-hoc basis in my course, *Introduction to Mechanical Prototyping*. The course is currently broken into two halves:

First half: Three rapid (2 week) individual and team-based design projects to familiarize students with computer-aided design software, static structure design, and basics of mechanisms.

Second Half: Three prototype iterations of a complex mechanical system that will compete in a final design challenge. Past examples include walking robot animals and robotic hands.

Future development goal: Shift from exclusively summative assessment (design reports) to combined summative and formative assessment via engineering portfolios.

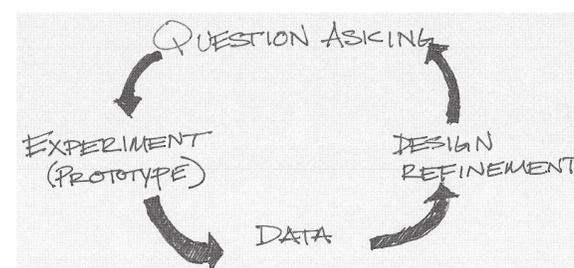
Learning Activities

The learning activities in this work are intended to shift the emphasis from course deliverables to a process orientation that favors learning through iteration and experimentation.

- **Conducting tabletop experiments:** Eg. students fabricate standard geometry beams from different materials, load them in a controlled way, and measure deflection in order to estimate material properties like Young's Modulus.
- **Creating iterative prototypes:** At least one design project will be assigned in which teams of students create multiple prototypes of a single mechanical system. Iteration on a single idea will encourage students to reflect on previous experiences and synthesize their learning to improve their design concepts.
- **Constructing engineering portfolios:** The primary tool that will be used to foster the prototyping mindset, reflective practice, and provide formative and summative assessment opportunities is the engineering portfolio. The engineering portfolio has the added advantage of accommodating many different learning styles.

DESIGN OBJECTIVE → PROTOTYPE → TEST → FINAL DESIGN

Students' early perception of the design process



The continuous prototyping approach

Execution

This project will be implemented in a course I currently teach, *Introduction to Mechanical Prototyping*.

To explicitly encourage the adoption of a continuous prototyping mindset, the course will focus on **iterative design of multiple prototypes** to compete in a design challenge. The semester-long challenge will entail the design, construction, and testing of a robotic hand for grasping and manipulating everyday, irregularly shaped objects.

Students will work in teams, but contribute individually to **online engineering portfolios**. Each week, students will create an entry in their portfolios with a set of **design questions**, a **tabletop experiment** designed to answer one of those questions, resulting **data, analysis/interpretation**, and **reflection**.

To help them design tabletop experiments, students will be guided to answering design questions using simple experiments. The guides will include basic relevant examples.

Issues to Resolve

- **Creation/configuration of web-based engineering portfolios:** I am comfortable setting up web-based tools like WordPress, but I don't yet know what the best tools for the creation and maintenance of online engineering portfolios are.
- **Design and implementation of tabletop experimentation guides:** Because the tabletop experiments will be conducted quickly, the guides should be scoped appropriately to enable students to design, execute, and analyze an experiment in one week's time.

Discussion

The underlying motivation for this project is to expose students to a process that enables them to contextualize their learning using techniques for continuous and iterative question-asking and question-answering. Mechanical design as it's traditionally taught presents derivations and equations with limited if any context. Yet, a given design is always done in a context that presents a unique set of constraints. My hope with this project is that students begin to use continuous prototyping to *proactively* explore the mechanical design space created by the intersection of real-world constraints.

What does success look like?

I frequently have the experience of students asking me for the "right" answer. One very clear indicator of success would be seeing students spontaneously designing experiments to attempt to answer design questions they've posed themselves before even considering asking the professor.

Acknowledgments

The concept for this work was inspired by a talk titled *Small Steps in the Dark: Embracing the Continuous Prototyping Mindset* given by Tim Ambrogio at the 2012 Game Developers Conference

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