All of Capstone in a Day Project

Eric Bogatin and John Lettang

University of Colorado, Boulder

Abstract

We introduced a simple one-day project at the beginning of our capstone senior design course, which gave students valuable insight into the importance of project planning and teamwork they leveraged throughout our 2-semester course.

Introduction

The ECEE department has offered a 2-semester-long capstone program for over 20 years. We typically have 90 seniors grouped into teams of six students. We constantly experiment with content and methods to make it more effective for the students and better prepare them for the semesters ahead and their future careers in industry.

Four years ago, we introduced a new one-lab-session long project that gave the students an introduction of what to expect in the capstone senior design project course. We call this the Moth Car Project. It is a chance for our students to experience what is ahead for them in the entire capstone course, all in one day.

The purpose of this project is to immerse students into the intense design-build-test-redesign experience of the capstone program and, most importantly, the value of working as a team. It gives students a taste of how important teamwork and team dynamics are in solving problems and accomplishing tasks on a deadline.

The project

On the first day of the semester, we meet as a whole class in a large lecture room. The professor presents an overview of the product development process and what is ahead for students in their two-semester program. At the end of the hour-long presentation, students go to the lab and find out which team they are on and meet their team members. They do a structured one-hour team-building exercise to get to know each other.

The second day of class begins the Moth Car Project. Students come to the lab and each team is given a kit of parts with a document describing the project. The only directions they are given are the following:

I, Prof. Bogatin, am your customer. I want you to design and build an autonomous car that seeks the light like a moth.

We will put your car on the floor in a dark room. I will turn on a flashlight. Your car should move to get as close as it can to the light. It should follow the light as I move the flashlight around.

Stretch goals:

- If there are obstacles or multiple cars on the floor, it should avoid hitting them.
- The Moth Car should indicate what its current battery level is.
- You have a strip of four smart LEDs. Incorporate them into your car for dramatic effects.

You have 2 ½ hours. Start your engines.

The figure below shows on of the teams setting up for their final test demo.

They can accomplish this task any way they want, using any resources they want. The kit contains all the parts they might need. Each bench has a toolbox with all the tools they

would need. They use this project to learn about what is available on their lab bench and in the rest of the lab.

This is not a competition between the teams. They are encouraged to share experiences with other teams, to ask instructors for help, and to use the Internet as a resource. Recently, we have seen teams leverage AI tools such as ChatGPT, Google Gemini, and Claude.

When they ask an instructor for additional resources, like double-sided tape, the answer is yes. Sometimes, when they want to use a microcontroller other than the Atmega 328 provided, the answer is no, and they have to develop a plan B.

The kit

We have used various starting kits for the autonomous cars. One from Adafruit is typical of our kits: Mini Round Robot Chassis Kit - 2WD with DC Motors : ID 3216 : Adafruit Industries, Unique & fun DIY electronics and kits. This kit is about $20. Other similar kits are available from ebay, such as this one: Avoidance Tracking Smart Robot Car Chassis Kit Ultrasonic module For Arduino 2WD | eBay for $10.

This kit is shown below.

What Students Learn

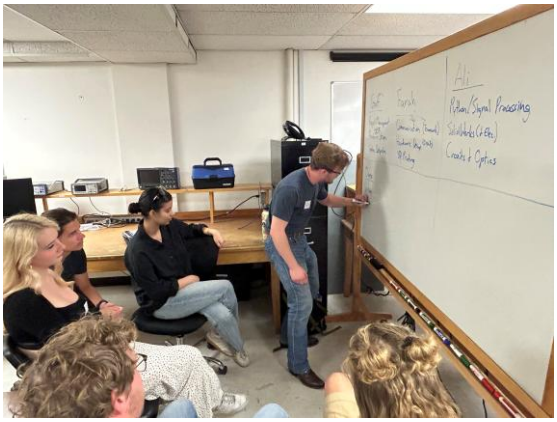
Regardless of whether their car is able to pass the final test, teams learn a valuable lesson. Most students could probably build a successful car from the kit if they had 6 hours. This

includes hardware construction, wiring, finding the drivers, writing the code, introducing the photo resistor sensors, and testing the unit. But the team only has 2 ½ hours. This means they have to learn how to work together.

As part of the documentation, I tell them they need to spend some time upfront planning. This includes assessing the skill sets of their team members and partitioning the project into pieces that can be done in parallel. They must have a schedule for when the subsystems will come together for final integration testing to make the deadline for the demo.

From feedback forms each student fills out at the end of the project, we find the most important lesson students learn is how important communication between the team members is at each step along the way. They invariably find that someone is moving down one path that is not aligned with the other paths.

The second lesson is how important a little upfront planning is. It is the natural tendency of every engineering student to want to jump right into building. They feel the urgency of the deadline and want to get started. However, they find that unless they have a plan shared by everyone, they may finish a task, but it does not contribute to the final project. We call this approach the “read, fire, aim” method or project planning. The figure below shows an example of a team spending a few minutes planning before jumping in.



Invariably, I hear teams telling me how valuable these two lessons are throughout their capstone experience. A little up-front planning will save time later and clear roles, responsibilities, and communication among the team members at each step along the way, make for a more successful project.

The figure below shows an example of everyone on the team with a part to play, collaborating closely together.

What the Staff Learns

We have run this project for four years and the results have been outstanding.

Generally, of the roughly 15 teams, 70% accomplish this task really well, finishing on time and demonstrating an autonomous car attracted to a light that can maneuver in the dark. They carry this taste of victory under pressure with them forever. These turn out to be the higher performing teams able to tackle more challenging projects.

Of the remaining 30% of the teams, it is generally split. Half the remaining teams get very close but just could not debug their cars before the deadline. There is often healthy team dynamics, but the team did not have a strong technical leader to direct the project.

The other 15% of the teams just spun their wheels and were not able to make much progress at all. This is generally due to a dysfunctional team, no strong technical leader and too many team members who have a very poor technical background and are not able to contribute at all to the project.

This is an important screening for the staff. Through this process, we identify those teams and team members who require special attention. In some cases, based on the lack of contributions we see from individuals, they are pulled off their teams and assigned a special project more suitable to their abilities.

The figure below shows one of the teams after their victorious demonstration.

Conclusion

The essence of the capstone course is experiential learning. It is a chance to apply the principles they learn in other classes to the real world of creating something of value from a concept, that is encapsulated in the Moth Car Project, a chance to experience all of the capstone course in one day.