Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #48141

Electric Vehicles in Electrical and Computer Engineering Programs

Dr. Afsaneh Minaie, Utah Valley University

Afsaneh Minaie is a Professor of Electrical and Computer Engineering at Utah Valley University. She received her B.S., M.S., and Ph.D. all in Electrical Engineering from the University of Oklahoma. Her research interests include gender issues in the academic sciences and engineering fields, embedded systems, machine learning, wireless sensor networks, and databases.

Dr. Reza Sanati-Mehrizy, Utah Valley University

Reza Sanati-Mehrizy is a professor of Computer Science Department at Utah Valley University, Orem, Utah. He received his M.S. and Ph.D. in Computer Science from the University of Oklahoma, Norman, Oklahoma. His research focuses on diverse areas such as: Database Design, Data Structures, Artificial Intelligence and Machine Learning, Robotics, Data Mining, and Computer Integrated Manufacturing.

Electric Vehicles in Electrical and Computer Engineering Programs

Abstract

Electric vehicles (EVs) are vehicles that employ one or more electric motors for vehicular propulsion, utilizing electrical energy as their primary or supplementary power source. EVs are typically categorized into four main types based on their energy storage and conversion mechanisms: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs), and Fuel Cell Electric Vehicles (FCEVs). These systems differ in architecture, control strategies, and energy management approaches.

From an environmental perspective, EVs offer significant advantages over conventional internal combustion engine (ICE) vehicles, notably in terms of reduced tailpipe emissions and overall greenhouse gas output, particularly when charged from low-carbon or renewable energy sources. Furthermore, EVs exhibit lower total cost of ownership (TCO) due to enhanced energy efficiency, fewer moving parts resulting in reduced mechanical wear, and the relatively low cost of electricity per unit of energy compared to fossil fuels.

The rapid expansion of electric vehicles has created a growing demand for engineers with expertise in this field. There is a recognized need for a large, well-trained workforce capable of conducting research and development projects in electric vehicle technology. However, the design and implementation of electric vehicles are not yet well represented in most undergraduate academic programs.

To better prepare our electrical and computer engineering students for careers in this evolving industry, we encourage them to select capstone projects related to electric vehicles. This paper presents two representative electric vehicle-oriented capstone projects undertaken by students in these two programs, showcasing their efforts to gain hands-on experience and practical skills in this critical area.

Introduction

The history of electric vehicles (EVs) dates to the early 19th century when inventors in Europe and the United States began experimenting with battery-powered transportation [1]. In the late 1800s and early 1900s, EVs gained popularity, particularly in urban areas, due to their quiet operation and ease of use compared to gasoline-powered cars [2]. In that time, electric taxis were used in cities like New York and London. However, the mass production of affordable gasoline vehicles, such as the Ford Model T, along with the expansion of fuel infrastructure, led to the decline of EVs by the 1920s [3]. Interest in electric mobility resurged during the 1970s oil crisis and again in the 1990s with environmental concerns and government regulations promoting zero-emission vehicles [4]. The modern rebirth of EVs began in the 2000s with advancements in lithium-ion battery technology, spearheaded by companies like Tesla [5]. Research indicates that while electric vehicles produce no emissions during operation, their manufacturing process generates more carbon emissions compared to internal combustion engine vehicles (ICEVs). This is primarily due to the production of lithium-ion batteries, which require the extraction and refinement of raw metals, processes that emit significant amounts of carbon. Additionally, studies suggest that the overall carbon footprint of an EV is influenced by the energy source used for charging. Charging with clean energy sources, such as solar or wind power, significantly reduces emissions, whereas reliance on fossil fuels, natural gas, and coal-fired electricity contributes to higher carbon emissions and is not a sustainable option [6]. With the rapid adoption of electric vehicles (EVs) and their potential for reducing carbon emissions, it is widely believed that EVs produce fewer harmful emissions, particularly carbon dioxide (CO_2), while also improving energy efficiency. Considerable research has validated the numerous benefits of EV adoption, with the advantages of battery electric vehicles being widely recognized. However, transportation-related emissions continue to rise in regions where mobility demand is increasing, and electricity generation relies heavily on fossil fuels, such as in China, the USA, France, and Germany. EVs have the potential to significantly reduce CO_2 emissions, especially when their batteries are produced using renewable energy sources [7].

The following are some of the advantages of using electric vehicles [8]:

- **Energy Efficient** - Energy efficiency describes how much of the energy from a fuel source is transformed into actual power that drives a vehicle. Electric vehicles, such as those from Tesla, are significantly more efficient than traditional gas-powered cars. All-Electric Vehicle (AEV) batteries convert 59 to 62 percent of energy into movement, while gas-powered cars only manage to convert 17 to 21 percent. Essentially, charging an AEV's battery delivers more usable power for driving than filling up a gas tank.

- **Require Lower Maintenance -** All-electric vehicles offer high performance with quiet, smooth motors and require less maintenance compared to internal combustion engines, eliminating the need for things like oil changes.

- **Reduce Emissions** - One of the key benefits of all-electric vehicles is their reduction in emissions and carbon footprint, including lower fuel consumption. Since they run on rechargeable batteries, electric cars produce no tailpipe emissions.

The following are some of the disadvantages of Electric Vehicles [8]:

- **Limiting Driving Range -** On average, AEVs have a shorter range than gas-powered vehicles. Most models offer between 60 and 120 miles per charge, with some luxury versions reaching up to 300 miles. In contrast, gas-powered vehicles typically average around 300 miles per tank, and more fuel-efficient models can go even further.

- **Expense of Electric Vehicles -** Electric vehicles typically come with a higher upfront cost, but owning an EV can save money in the long run due to lower maintenance needs and cheaper charging compared to fuel.

- **Longer Fueling Time -** Fueling an electric vehicle can pose challenges as well. Using a Level 1 or Level 2 charger, fully recharging the battery can take up to 80 hours, and even fast-charging stations require about 30 minutes to reach 80% capacity.

Background Information

Utah Valley University (UVU) is a large regional institution serving over 46,000 students in Utah County, the state's second-largest county. UVU is regionally accredited by the Northwest Commission on Colleges and Universities. The university has a dual mission: it offers 91 bachelor's degrees and 11 master's degrees as a comprehensive university, and it also provides 65 associate degrees and 44 certificate programs as a community college. To fulfill its community college mission, UVU maintains an open-enrollment policy. The university serves a diverse student body, with 38% of students being low-income and 41% being first-generation. Additionally, UVU has a significant population of non-traditional students, including 29% who are older than the typical college age, 35% with spouses, and 19% with children under age 12. Despite relatively low tuition, 36% of degree-seeking students attend part-time. These factors contribute to the university's overall graduation rate of 33% (as measured by the national IPEDS standard for completions in 150% of normal time) and a 70% one-year retention rate for baccalaureate degree-seeking students.

Electrical and Computer Engineering Department

To address a critical workforce demand in the region, UVU launched new bachelor's programs in Electrical, Civil, and Mechanical Engineering in Fall 2018. These joined existing Computer and Pre-Engineering programs to form the Engineering Department, which grew rapidly—from 300 students in its first semester to over 900 by 2023.

In Fall 2024, the department was reorganized into two: Mechanical and Civil Engineering, and Electrical and Computer Engineering (ECE). The ECE Department now serves over 250 students and offers ABET-accredited programs in Electrical and Computer Engineering.

UVU maintains open admissions practice; however, entry into the ECE programs requires completion of specific prerequisite courses with minimum grade and GPA standards.

Electrical Engineering Capstone I and II Writing Enriched (WE) Courses

Capstone courses play a crucial role in Electrical Engineering (EE) curricula. These courses provide graduating seniors with a culminating experience that integrates the knowledge and skills developed throughout their academic career, preparing them for real-world engineering challenges.

Like many engineering programs, UVU's EE students complete a two-semester capstone design sequence as a graduation requirement. These courses allow students to apply competencies gained during their first three years to solve an engineering design problem. Our senior design courses are structured as a collection of independent student projects. As our students are required to design, build, test, and troubleshoot a fully functional system, they find these courses both challenging and rewarding.

The primary objectives of senior projects are to simulate industry-relevant project development and to build expertise in four key areas:

- Teamwork

- Project Management
- Research & Development
- Communication

These are the most important skill areas to the success of an engineer.

Capstone I Course (ECE 4900)

Capstone I is the first course in the two-part senior design sequence. In this course, students complete several key milestones:

1. Team formation
2. Project proposal and approval
3. Project planning
4. Procurement of hardware components
5. Proof of concept for critical circuits
6. Preliminary Design Review (PDR)

Topics covered include:

- Engineering design methodology
- Project selection and need Identification
- Requirement specification development
- Concept generation and evaluation
- Team dynamics and collaboration
- Ethics and legal considerations in engineering
- Basics of Engineering Economics

Each team meets weekly with a faculty advisor to review progress, troubleshoot challenges, and provide regular status updates. Students are expected to commit approximately 10 hours per week, totaling 150 hours over the semester. A final letter grade is awarded based on project performance, participation, presentation, weekly and final reports, and milestone completion.

Capstone II (ECE 4950)

Capstone II is the second course in the senior design sequence required for graduation. The course requires the completion of the following major milestones:

- Fulfillment of proposal commitments

- Functional project demonstration

- Completion of documentation and poster

- Final Design Review

- Submission of an abstract to a conference (if accepted poster presentation)

- Developing a poster for presentation at a college wide design expo (CET Expo)

Capstone I (ECE 4900) is a prerequisite for this course. Capstone II does not have a scheduled lecture component. Instead, students meet weekly with their faculty advisor to review progress and receive guidance.

The primary outcome of Capstone II is a comprehensive written project report. This document must thoroughly describe the project, providing sufficient detail and clarity so that someone with a general background in electrical and computer engineering—but no prior knowledge of the specific project—can fully understand the work.

In addition to the written report, students will deliver a formal oral presentation to an audience that may include faculty, students, industry professionals, and members of the public. This 30-minute session (which includes time for setup and teardown) will require students to:

- Present their project at a level suitable for a general engineering audience.
- Demonstrate any functional systems or components.
- Answer questions regarding their design, implementation, and results.

As part of UVU's graduation requirements, all bachelor's degree students must complete at least two Writing Enriched (WE) courses. WE courses are designed to integrate meaningful writing into the curriculum—not as standalone writing classes, but as part of the learning process within each discipline.

WE courses include a mix of high-stakes writing assignments (such as formal technical reports) and frequent low-stakes activities (such as logbooks or design reflections), along with targeted instruction to improve students' writing and communication skills.

In the Electrical Engineering program, both Capstone I and Capstone II courses are designated as Writing Enriched courses, satisfying this university requirement.

Computer Engineering Senior Design Project Course (ECE 4800)

Computer Engineering students at UVU are required to complete a one-semester capstone design course as part of their graduation requirements. This project-based course focuses on the integrated design of hardware and software systems through collaborative team efforts, offering students a substantial, hands-on engineering experience reflective of industry practices. Additionally, it satisfies the ABET accreditation requirement for a major design experience within the curriculum [9].

The course is organized around a series of open-ended, student-initiated projects, each developed in collaboration with a faculty advisor. These student-driven initiatives demand a high level of instructional flexibility, in-depth knowledge of available hardware and software resources, and the capacity to guide students toward feasible and technically sound project concepts. Although this pedagogical model introduces certain instructional challenges, it also yields substantial educational benefits—enabling students to engage deeply with the engineering design process while cultivating essential skills in problem definition, analytical thinking, and solution development.

Throughout the course, students follow a structured design methodology that typically includes:

- Defining the problem and constraints
- Conducting background research
- Generating and evaluating design concepts
- Developing preliminary and detailed designs
- Communicating results effectively
- Iterating and refining solutions as needed [10]

Our capstone course is designed based on the Engineering Design Process, as outlined in Table 1 [11].

Engineering Design	
Requirement Analysis	**Identify the problem and constraints** **Define goals and criteria**
Functional Analysis	**Research and gather data**
Design Synthesis	**Brainstorm: Develop Possible Solutions** **Analyze potential solutions** **Model and test candidates** **Select a promising solution** **Build a Prototype** **Test and evaluate prototype** **Implement** **Communication of Results**
System Analysis and Control	**Improve: Review and redesign as needed**

Table 1: Engineering Design Process [11]

The objectives of this course are as follows:

- Identify and apply relevant concepts from prior coursework to their design project
- Extract and define design requirements from general problem statements
- Communicate technical ideas effectively, both in writing and orally
- Demonstrate creativity in problem-solving
- Develop effective information-gathering and research skills
- Exhibit strong written and oral communication competencies

ECE 4800 is offered each semester and is typically undertaken during a student's final term in the Computer Engineering program. Students have the option to propose their own embedded system projects or select from a list of advisor-approved topics. In the first week of the course, each student submits a comprehensive proposal that outlines the problem, proposed solutions, and required hardware and software components. This proposal is subject to revision and must be refined until it receives approval from the faculty advisor.

Mandatory weekly one-on-one meetings between the student and advisor are scheduled at mutually convenient times. These meetings serve to review project progress, address technical challenges, and establish goals for the upcoming week. Students are required to maintain a detailed daily journal/work log that tracks time spent, tasks completed, and critical technical notes. The advisor also keeps a record of each meeting, including feedback and assigned action items. Reviewing the previous week's log ensures continuity and reinforces the value of each meeting.

At the end of the semester, students submit a final written project report and deliver a formal presentation, which is evaluated by a panel of faculty members from the ECE department.

Integration of Electrical Vehicles Education in Computer and Electrical Engineering Programs at UVU

Today's engineering students must learn in an environment of continuous technological change and innovation. To meet this challenge and prepare them for the future workplace, students are trained to become content experts, skilled problem solvers, and effective team players. Instructors are dedicated to creating learning activities that foster these essential skills and equip students to undertake 21st-century workplace challenges.

Currently, most electrical and computer engineering programs offer limited exposure to electric vehicle analysis and design. While we do not yet provide a dedicated course on electric vehicles, our capstone courses allow students the flexibility to pursue projects that align with their interests. In recent years, several electrical and computer engineering students have chosen to focus on electric vehicle technology.

The following sections highlight a sample project completed by our electrical engineering students, followed by a project undertaken by our computer engineering students.

Electrical Engineering Project: E-Bike Conversion Kit

This capstone project was sponsored by the College of Engineering and Technology through Engineering Initiative Funds. The project's objective was to design an affordable and user-friendly retrofit kit capable of converting an old mountain or street bicycle into a fully automated electric bike.

Electric bicycles have gained significant popularity in recent years as a sustainable and cost-effective mode of short-distance transportation. However, the high cost of purchasing a new e-bike continues to be a major obstacle for many individuals seeking to transition to this eco-friendly alternative. Recognizing this challenge, two electrical engineering students dedicated two semesters to developing a viable solution.

Motivated by their interest in combating global warming, the students aimed to create a product that encourages the adoption of environmentally friendly transportation options. The primary goal of the E-Bike project was to provide a practical and accessible solution for short-range commuting, making electric biking available to a wider audience. Through extensive research and development, the team conceptualized a retrofit kit designed to transform conventional mountain or street bicycles into electric bikes. Figure 1 illustrates the original bicycle used in their project [12].

Figure 1: Original Conventional Bike [12]

The E-Bike Conversion Kit that they designed includes a 48V, 20 Ahr lithium-ion battery cell that distributes power through a charge controller. The 48V power supply provides sufficient torque to enable an average adult to ascend hills with ease, while the 20 Ahr capacity allows the rider to maintain maximum speed for up to an hour without requiring a recharge. Battery lifespan can be extended by avoiding full throttle usage or complete reliance on the electric motor. Utilizing the motor as an assistive feature can significantly enhance battery longevity [12].

An additional design feature of this bike was its alternative charging method. The solar charge controller harnesses energy from a 100W portable solar array, offering off-grid recharging capabilities. The 1000W front-wheel electric motor delivers enough power for hill climbing and allows commuting at speeds exceeding 20 mph [12].

An LCD display, mounted on the handlebars, provides real-time information, including current speed, trip length, and remaining battery charge. The primary electrical components are housed within the bike's main subframe, enclosed in a weatherproof plexiglass box. Figure 2 shows the system diagram for their design and Figure 3 shows the electric bike that they designed [12].

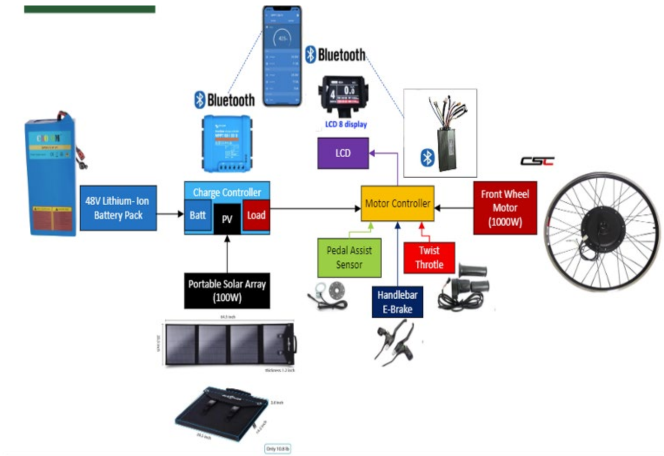

Figure 2: System Diagram (E-Bike) [12]

Their E-Bike Conversion Kit offers standard bike owners an affordable way to convert their existing bicycles to E-Bikes.

Figure 3: Retrofitted E-Bike [12]

The project was a success, offering students valuable experience in managing a design project and developing a product aimed at positively impacting low-income individuals. They effectively showcased their work to the public, industry representatives, and fellow students during the Capstone Day event.

Computer Engineering Project: Electric Go-Kart

The goal of this capstone project was to convert a gas-powered go-kart into an electric go-kart. Two computer engineering students dedicated one semester to working on this project, funding it themselves. Figure 1 displays the gas go-kart they purchased for the conversion.

Figure 4: Original Shifter Kart [13]

The students added electric motors, batteries, microcontroller, microcontroller box, motor speed sensors, acceleration/deceleration sensors, potentiometers, voltage and current sensors to the purchased Go-Kart. They used two electric motors: one for each rear wheel. The electric motors were used to replace the differential/axel connecting the two wheels together.   Figure 2 shows the circuit that was designed [13].

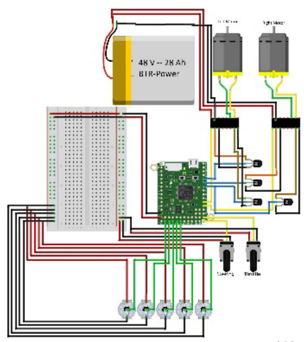

Figure 5: Circuit Design [13]

Figure 6 shows their final design.

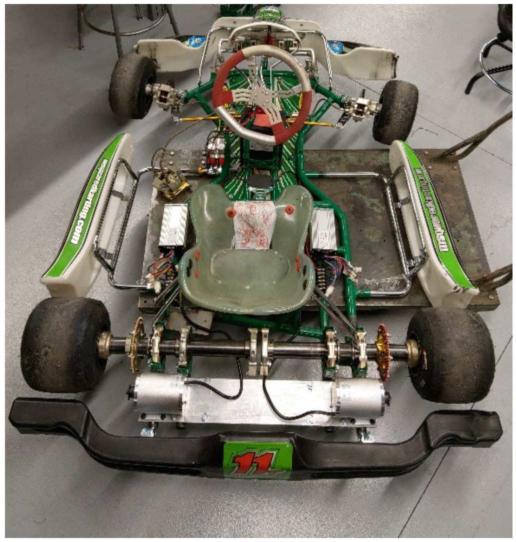

Figure 6: Electric Go-Kart [13]

The project was a success, and one of the students shared positive feedback upon its completion, stating, “All in all, the project was a success, and I had a blast building it.”

Conclusion

This paper presented recent capstone projects in electric vehicles undertaken by our electrical and computer engineering students. Our undergraduate senior design course and capstone courses are structured as a collection of independent student-led projects. Students find these courses both challenging and rewarding, as they are required to design, build, and troubleshoot a fully functional system. These projects provide an opportunity for students to apply the technical knowledge and skills they have acquired throughout their studies.

Throughout the semester, students dedicate significant effort to ensuring their projects are fully operational. The courses offer numerous opportunities for self-directed learning, allowing students to develop essential skills such as debugging, researching and acquiring necessary information, and interpreting or reverse-engineering poorly documented materials.

Student feedback and final project presentations demonstrate a strong sense of pride in their accomplishments and increased confidence in their engineering capabilities. The senior capstone design courses continue to be a vital and engaging component of undergraduate electrical and computer engineering education.

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