# Integration of First-Year Engineering Students into Research: 4 Year Data from the Electrical Vehicle Project (EVP)

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## Abstract

This paper describes how to integrate first-year engineering students into an ongoing research project to further promote education and enthusiasm for the realities of the engineering profession. The two methods used were (1) parallel process and (2) self contained process. A parallel process is used when the research project or selected portion of the project is too complex or expensive for first-year students due to lack of knowledge or experience. Self contained process is used when less complex or expensive portions of the project can be completed by first-year students. Both processes were used in the Electrical Vehicle Project (EVP) at the University of Arkansas – Fort Smith. This paper concludes with detailed suggestions in selecting and implementing these processes for projects with which the reader is engaged.

## Introduction

The University of Arkansas – Fort Smith in conjunction with the University of Arkansas - Fayetteville offers bachelor degrees in Electrical and Mechanical Engineering. The Fort Smith campus is responsible for the first two years of the degree and additional interactions with senior design students; there is not a graduate engineering program in Fort Smith. With this in mind, the student population used in research projects is limited to freshman, sophomores, and senior design students, reducing the scope and complexity of the research that can be conducted. These constraints have prompted evolution of the processes described in this paper.

The Electric Vehicle Project (EVP) began in 2006 with a student led proposal submitted to Baldor Electric Company, the largest domestic producer of electric motors and drives, which netted the research team donated supplies and services. EVP is a multi-year research project emphasizing the construction and testing of an electric vehicle that possesses modern features such as air conditioning. The heart of the research project is using a Controller Area Network (CAN) to improve vehicle range and battery management. Additionally, this project has been enthusiastically supported by local businesses and has been used to interest precollege age students by exposure to this technology in a public school setting.

Actively engaging first-year engineering students is critical to program retention and developing excitement about the profession[1,2,3]. Involving these students in one's research project is a logical step with benefits for the learner[4] and educator. The student benefits from seeing the application of the engineering process and experiencing tangible results of their work. The educator benefits by effectively using their time budgeted for research and critical interactions with students with resulting greater productivity in completing project tasks.

Process selection should address different learning styles and address evaluation metrics; experience has shown both to increase class participation. Since many engineering students are inductive learners[5], the process can be tailored to accommodate this learning style; this will allow students to learn at their own pace using a discovery method (self directed learning). Process selection should also address class knowledge base and experience. To ensure a successful learning experience, these considerations must be addressed during the development phase of the selected process. Other ancillary benefits of using these methods are project management, maintaining realistic budgets, Gantt charts, investigating funding opportunities, teamwork, real-world time demands, task completion, written and oral communications, and public demonstrations.

The remaining portion of this paper is broken into five sections: first-year engineering student training, description of the parallel process, description of the self contained process, discussion of evaluations and results, and suggestions in selecting and implementing either of the two discussed processes.

**First-year engineering student training**

To ensure the participating first-year engineering students have a basic understanding of needed concepts and equipment operation, several key concepts and review of equipment to be used in the EVP were covered in the first half semester of Introduction to Engineering II and tested at Midterm. Table 1 below lists concepts and equipment used in Introduction to Engineering II.

**Table 1: Topics covered in Introduction to Engineering II that are used to complete related EV projects.**

| Topics Covered in Introduction to Engineering II | Description |
|---|---|
| Safety | How to handle and prevent electrical and thermal injuries |
| Resistor Color Codes | How to read the color bands on resistors |
| Digital Multimeter (DMM) | How to make voltage, current, and resistance measurements using the DMM |
| Oscilloscope | How to determine peak, frequency, period, and duty cycle using the oscilloscope |
| Soldering | How to make reliable solder connections |
| Power Calculations | How to determine the power required for an EV |
| Calculating Velocity, Acceleration, Force, Torque, Rolling Resistance, and Air Resistance | How to calculate these values for an EV |
| Designing Digital Logic and Controls | How to gain a basic understanding of number systems, digital logic and their use to control devices |

**Parallel process description**

The parallel process is most effectively used when the project or selected portion of the project is too complex or expensive for first-year engineering students to effectively complete. Table 2 below lists some parallel processes that were used on the EVP; column one lists tasks that were completed by senior design students on the actual EV and column two lists tasks completed by first-year engineering students on an electric golf cart. A golf cart was used because the electric drive system, batteries, and a programmable controller are similar in nature to the fully functional EV.

**Table 2: This table compares tasks completed by Senior Design Students and First-year Engineering Students on the EVP. These tasks illustrate the use of the parallel process.**

| **Senior Design Students' Tasks (actual EV)** | **First-year Engineering Students' Tasks (golf cart)** |
|---|---|
| Programming CAN microcontroller | Programming AllTrax ControlPRO |
| Designing and constructing the battery management system | Working with Baldor engineer to build battery charger |
| Designing on-board electrical system | Changing from 36 VDC to 48 VDC system and adding lighting to the golf cart |
| Use of a Gant chart | Use of a Gant chart |

To illustrate the parallel process, two items from Table 2 will now be discussed. Consider programming the microcontrollers for the Controller Area Network (CAN) for an EV which would require knowledge of $C^{++}$ or assembly language plus an understanding of registers and timing; this requires knowledge and skills that most first-year engineering students do not have. Some of the same concepts such as maximum output current, throttle up and down rate, and top speed can be taught using AllTrax ControlPRO software that utilizes a graphical interface. This software allows first-year students the ability to adjust these parameters plus other settings and measure the outcomes. Both seniors and first-year students make these same measurements on their respective vehicles.

Another parallel process listed in Table 2 is designing the on-board electrical system. The fully functional EV started with a donated, salvaged 1991 GEO Metro; the automobile was produced before many modern features were introduced such as CAN. Additionally many of the electrical circuits were damaged due to weather exposure and required replacement. This apparent drawback has provided an opportunity to install newer and more efficient on-board electric circuits with more functionality. One key concept that must be considered when designing these electrical systems is power consumption. In the case of the golf cart and the first-year students, a donated 1996 Club Car base was used which operated on a 36 VDC system and did not have a lighting system installed. The first-year students were tasked with increasing the on-board voltage to 48 VDC and designing/installing head lights, tail lights, brake lights, and turn signals. These first-year students were tasked to consider power requirements and the most effective use of the batteries.

After these first-year engineering students work with the electric golf cart, they are better equipped to understand and work on EV project technology.

**The self contained process description**

Some parts of the EVP lend itself to both senior and first-year engineering students working in tandem while some parts of the EVP could be completed by first-year students alone or with guidance from the seniors. Table 3 below highlights some projects that were completed with these students working side-by-side.

**Table 3: This table illustrates projects that were completed by first-year students alone or under the direction of senior design students.**

| Project | Description of Student Participation |
|---|---|
| Vehicle Clean-up and Part Removal | First-years alone |
| Mounting brackets | Seniors/first-years help construct |
| Battery Compartment Design | Seniors/first-years help construct |
| Lighting System | First-year Students |

To illustrate the self contained process, two items in Table 3 will now be discussed. One simple but necessary project was vehicle clean-up and removal of nonessential parts. The GEO Metro was removed from an open air salvage yard containing unwanted debris and water damage. The first- year engineering students were tasked with removing the debris and power washing the outside and inside of the vehicle. The second phase of the project was removing parts associated with the combustion engine, transmission, emission, and fuel tank. Students gain valuable experience by removing vehicle parts and better understand the functional components of an automobile. As noted, the first-year students could work independently on these projects.

Another self contained process was designing a battery compartment. In order to make the EV operable, 14 lead acid batteries needed to be housed on the vehicle. This presented several challenges such as weight distribution and battery position. Before the final battery compartment design and position decision was made, a wooden mock-up was constructed by the first-year engineering students. This provided an inexpensive way to place batteries in the vehicle, make critical measurements, and allow the vehicle to be operated. This self contained process reduced senior design student time requirements and allowed the first-year students a valuable contribution to the EVP.

## Evaluations and Results

The first-year students were evaluated on three key research components with the following course percentages: class participation (10%), project presentation (10%), and project logbook (20%). Each student was responsible for completing their assigned task which was the main constituent of the class participation grade. The other component was the ability to work on a team effectively; this component was subjectively evaluated by the course instructor. Near the end of the semester, each student or team of students gave an in-class presentation over their portion of the assigned project. This included calculations, budget, and results. Another factor in their course grade was the project logbook. Each student was responsible for keeping accurate notes for each day they worked on the project. Students were asked to record successes, problems, problem resolution, and research notes. Each day the logbook was dated and signed. The emphasis placed on these three project components should lay the ground work for better individual future research performance.

First-year students that were involved in EVP were surveyed on attitudes and gained knowledge. Students surveyed about the EVP for fall 2006 and spring 2007 were involved with researching and preparing a proposal submitted to Baldor Electric Company which netted the electric motor used in the vehicle. Students surveyed spring 2008 and 2009 were involved with hands-on activities related to the EVP.

Students in fall 2006 were surveyed with 86% responding that the EVP was a course highlight. 71% of these students responded they were much better equipped to develop and give public presentations after this course. Students in spring 07 were surveyed with 90% responding that the EVP was a course highlight. 100% of these students responded they were much better equipped to develop and give public presentations after this course. Students in spring 08 were surveyed with 78% responding that the EVP was a course highlight. 89% of these students indicated that they intended to continue their engineering major. Students in spring 09 were surveyed with 66% directly mentioning the EVP as the course highlight and 100% responding that they intended to continue their engineering major. Other favorable factors that were also mentioned on the student surveys and directly link to the EVP were plant tours, team work, hands-on activities that related to course content, and developing more personal self initiative.

## Suggestions for process selection and implementation

When deciding if a research project is appropriate for involvement of first-year engineering students, four factors must be considered: (1) complexity, (2) training, (3) expense, (4) student experience. Each factor is discussed below.

(1) An educator should consider if their research project can be broken down into simple tasks. If this is possible, then a self contained process could be used; small portions of the project could be assigned to a group of first-year students with minimal oversight. However, if the project is too involved for first-year students, a parallel process could be used to convey the concepts to these students.

(2) An educator must take inventory of the knowledge and skills possessed by their group of first-year students. If time does not allow proper training during the semester to utilize the self contained process, then the parallel process should be selected. This would afford the students an opportunity to better understand the concepts involved in the project.

(3) The expense of material and equipment used in the project must be considered when deciding on first-year student involvement. If the hazard of material waste or equipment damage is great, one should select a parallel process. This would ensure the students are exposed to the research but limits the down side of their involvement.

(4) From semester-to-semester the knowledge base and experiences change for each group of first-year engineering students. There have been semesters where several students in Introduction to Engineering II have had considerable training and experience in automobile technology. In these semesters, more responsibilities and complex project tasks can be completed by these groups. In these cases, the researcher/instructor must use his or her discretion on which process to use.

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**Bibliographical information**

KEVIN R. LEWELLING received his BS in Industrial Management 1989, MS in Electrical Engineering in 1992, and PhD in Electrical Engineering in 1997. Dr. Lewelling's technical background is in optics and infrared lasers. He has over ten years of experience in higher engineering education and is a licensed professional engineer.