

# EXPERIMENTAL VEHICLES PROGRAM RESEARCH AND INNOVATION PREPARES STUDENTS FOR CHALLENGES OF TOMORROW

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## Abstract

The Experimental Vehicles Program (EVP) in the Engineering Technology Department at Middle Tennessee State University (MTSU) promotes innovative thinking through applied research projects. The rising demand for inventive technology has had a strong influence on modern national and international engineering technology curricula over the past several years. Competent, innovative engineers are needed now more than ever to help solve some of the most complicated problems in the advancement of the engineering technology industry. The various projects of the EVP allow engineering technology students to apply their innovative ideas and classroom knowledge to real-world problems. Projects such as the Moonbuggy and Solar Boat supply a creative environment for nurturing and inspiring innovative thinking, which allows students to generate groundbreaking technologies such as the carbon-fiber structure used in the Moonbuggy. These projects also provide invaluable experiences that give EVP students a competitive edge in the job market upon graduation.

Middle Tennessee State University engineering technology students must function together as a team to design, build, test, promote and race each vehicle in national and international competitions. The teams also disseminate their knowledge to the local middle and high schools to promote interest in engineering technology. The students take their completed vehicles to local schools to raise awareness of the program as well as the possibilities of what a future could hold when entering into a scientific, technological or engineering technology field. The innovative projects have increased interest in engineering technology, incorporated classroom learning into hands-on experiences, and fostered an atmosphere of peer-led team learning, which has benefited the students both personally by improving their interpersonal and career skill sets and academically by providing hands-on engineering technology experiences.

## Introduction

The Experimental Vehicles Program (EVP) was created in 2004 as an extracurricular umbrella program for five dif-

ferent undergraduate experimental vehicles including the Solar Vehicle, Moonbuggy, Baja SAE, Formula SAE and Solar Boat. Each EVP project is comprised of a team of students from various Science, Technology, Engineering, and Mathematics (STEM) disciplines throughout the university. Each project team, made up of approximately twenty to thirty students each, works to design, construct and test novel vehicle designs for participation in annual national and international competitions. The undergraduate design teams, which collectively form the EVP, are offered at various universities nationwide. However, the combination of all five design teams under one umbrella program makes the Experimental Vehicles Program at MTSU unique. The consolidation of the five design teams into the EVP improves the sharing of resources and expertise between students and faculty of different backgrounds.

Over the past several years, EVP team members have competed in a variety of national and international events. Each year, the students create a new, increasingly efficient, well-made vehicle for each of the projects. Success at this level not only means winning awards, but it is primarily the reflection of the innovation and dedication of the students. The unique research projects provide great benefits for the professional development of MTSU STEM students. Hands-on learning is a direct application of classroom concepts. In addition, these particular projects help students learn to think innovatively, communicate professionally, manage projects efficiently, and work in a team environment [1]. The competitions are also an opportunity for MTSU students to associate with other students from engineering schools around the country and globe [2]. Although most participants represent engineering and engineering technology majors, students from various disciplines have participated within the program.

Each year, students think creatively to design their blueprints, construct each vehicle from scratch, and enter each project into its respective competition. Each competition is composed of several events, providing a unique set of challenges along with racing against some of the top engineering schools in the nation, including the Georgia Institute of Technology (the 4th-ranked engineering school in the U.S.), the University of Illinois Urbana-Champaign (ranked 5th)

and Cornell University (ranked 11th) [3]. Students work diligently on these projects and incorporate skills needed in the workforce such as project management, decision making, leadership, critical analysis and problem solving. EVP participants learn the value of research, teamwork and effective communication. They learn to incorporate innovative ideas into a single goal, complete projects, and excel at competitions. In addition, the national and international design competitions provide valuable exposure for Middle Tennessee State University [2].

## Middle Tennessee State University's Solar Boat

Middle Tennessee State University offers several nationally competitive experimental vehicle projects as extracurricular activities for undergraduate STEM students [4], including the Solar Boat project. The Solar Boat project was founded following the inception of the Institute of Electrical and Electronics Engineers Power Electronics Society's Solar Splash Competition, an international collegiate competition showcasing solar/electric boating [5]. The Solar Boat project focuses on the capture, utilization and storage of solar energy to power a special-purpose boat. The boat design must follow a set of regulations to accomplish numerous pre-determined outcomes [6]. Nevertheless, the students are given a large amount of freedom in the design and operation of their Solar Boat. The project culminates at the annual five-day competition, where the students showcase their efforts and compete against other student design teams in various categories [5].



**Figure 1. Solar Boat during Competition**

The Solar Splash Competition can be classified as a “brain sport,” an activity giving STEM students an opportunity to experience real-world design and engineering

problems [7]. Students utilize their classroom knowledge of engineering principles while simultaneously developing valuable soft-skills such as teamwork and communication [4]. The overall effect of the project is an enjoyable, educational and engrossing experience for the students, which encourages the exploration and pursuit of engineering technology and solar technology.

The overarching theme of the Solar Boat project is to encourage students to excel in their studies and to get them excited about solar energy. It has been noted that past Solar Boat students became so interested in their projects that they actively pursued careers in the solar and other alternative energy fields. The project provides the fundamental knowledge and hands-on experience valued by employers, and serves to fill in any gaps in understanding from the students' classroom education.



**Figure 2. Solar Boat at the Solar Splash Competition**

During the Solar Boat project, students are faced with challenging dilemmas that are best solved through creative problem solving. For example, the 2012 Solar Boat incorporated an innovative drivetrain system. The drive system provides adjustable trim, while simultaneously facilitating rudderless steering. This groundbreaking steering integrates interchangeable motors, transom-mounted surface drive, interchangeable sprockets for variable gear ratios and surface-piercing propellers. This type of innovative drivetrain had never before been attempted at MTSU.

The Solar Boat project provides a creative outlet for engineering technology and other STEM students. The peer-led environment provides a congenial and supportive network, while the project itself begs for clever and imaginative approaches. Solar technology provides a plethora of challenges in its capture and utilization and, when applied to its application in a vehicle, gives the students a foundation on which to focus their efforts.



**Figure 3. MTSU Student-designed Innovative Drivetrain**

Students are often awarded for their creativity at the annual competition, where certain aspects of the Solar Boat, such as most outstanding hull design, are duly recognized and rewarded. Creativity must be supported and cultivated among students of engineering technology, as they are not as restrained by conceptual barriers that may cloud the mind of an experienced engineer [4]. The future success of solar energy will no doubt be the product of a collection of unconventional “outside-the-box” ideas generated by a new generation of inventive engineers.



**Figure 4. Blue Raider Solar Boat Team**

The Solar Boat project takes engineering technology students beyond classroom learning. Though students may amass a large amount of knowledge in the classroom and feel confident in their abilities prior to graduation, they could feel overwhelmed once entering the workforce, deterring them from remaining in an engineering field. Difficult or seemingly esoteric concepts can be made clear through

direct application or visualization via a hands-on undergraduate engineering project. Through the active development of the Solar Boat, students gain appreciation for the development of a design from the concept and cost-analysis phases through final production. The students learn how to respect both ergonomic and equipment restraints—a fundamental consideration for all practicing engineers. However, they also work in an environment that encourages the freedom to develop alternatives to the given challenges. Solar energy is a field full of potential and unexplored avenues, and students on the Solar Boat Team are given a unique perspective on the issue and are motivated to design something new and different. These students are less likely to conform to textbook solutions when exposed to similar challenges upon entering the workforce [4].

## Moonbuggy

The Moonbuggy project is a versatile vehicle that has inspired MTSU undergraduates to create novel engineering innovations. The Moonbuggy is designed to be a lightweight, compact, flexible and durable all-terrain vehicle. According to the NASA-sponsored Great Moonbuggy Race rules, the vehicle must be human powered and controlled by one male and one female student over a half-mile simulated lunar terrain, full blown with craters, lava ridges, rocks, inclines and lunar soil. The vehicles are judged on the performance over the terrain and the overall design. Students involved in the project each year work diligently to incorporate new and innovative designs to enhance the performance of the Moonbuggy over the lunar topography. Brainstorming prior to the fabrication of the vehicle has led to exciting inventive breakthroughs such as the carbon-fiber frame. This material is ideal for a lunar vehicle, due to its exceptional strength-to-weight ratio that allows easy maneuverability in a low-gravity atmosphere.

Between 80% and 90% of all vehicle fabrication and assembly is carried out in MTSU’s Voorhies Industrial Studies Complex in a dedicated workspace. Every year, students pay close attention to the wheels of the vehicle, fabricating them entirely in the engineering laboratories at MTSU. Some of the most innovative discoveries by the EVP students came a few years ago when the wheels were constructed from 1/2” aluminum stock and measured twenty-one inches in diameter, with a 2.5” tire. The design consisted of six identical sections bolted to a central aluminum plate. The spokes were made on a CNC machine from a design that eliminated the imminent strength problems that most teams encounter with classic bicycle spokes. The spokes increased the strength of the wheels but allowed for the replacement of only the affected part in the event of damage.



**Figure 5. Revolutionary Aluminum Stock Wheel**



**Figure 6. Six-wheeled Moonbuggy during Competition**

Last year's Moonbuggy team took thinking outside of the box to a new level when they designed a competition vehicle containing six wheels instead of the usual four. This groundbreaking vehicle design was the first of its kind to be used in the Moonbuggy competition. The six-wheel design allowed the vehicle to be streamlined; the vehicle was able to maneuver around the competition course with incredible flexibility and speed.

## Program Implications

### Retention and Graduation

The aim of all collegiate engineering technology programs is to produce sophisticated and talented engineers

who are ready to enter the workforce upon graduation. Many students may leave the engineering discipline or choose not to pursue such a career because they lack confidence in their knowledge and abilities, namely in mathematics and science. The EVP projects seek to encourage students to put their hands on an actual project and gain experience regardless of their opinion of their engineering skills. At the beginning of the project there is no right or wrong solution, and students of all backgrounds and skill levels combine their ideas as they work towards a common goal. The learning objective of such a project is to test out a variety of theories and methods and to investigate the consequences of each decision. Mistakes are seen as learning opportunities for the future. Even if a student lacked confidence in his or her abilities as an engineer, such hands-on experiences are often the spark that fires the creative imagination that causes the student to become fascinated with solar energy and the future of alternative fuel, making him or her more likely to continue studying engineering and engineering technology.

The introduction of hands-on, experiential learning projects aimed towards engineering technology and STEM students can provide them with a solid environment in which to build confidence as they hone their professional skills. Projects which focus on a major societal crisis such as solar energy can further encourage the students to explore a novel and critically important field of technology [8]. The benefits of such solar-focused engineering technology projects are two-fold: 1) students are encouraged to study engineering technology, and 2) they become intimately involved with the specialized technology, making them more attractive to potential employers upon graduation.

While the Solar Boat and Moonbuggy projects have been a major cornerstone in getting students involved and interested in engineering technology, they have also been key players in retention and recruitment that the EVP also prides itself on. Current estimates report that less than five percent of college-bound high school seniors are interested in pursuing a degree in engineering [9]. Of the relatively few students who begin their college career in engineering technology, many will abandon the field of study. While it is difficult to pinpoint exactly what motivates students to leave their engineering technology studies, it is important to note that engineering technology disciplines are often regarded as the most difficult category of majors at the collegiate level. Due to the engineering technology discipline's reputation for being extremely challenging, it is vital for engineering technology educators to take action to improve enrollment and retention rates through the implementation of unique student projects and programs [10].

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Middle Tennessee State University's Experimental Vehicle Program's projects are just one example of a valuable teaching tool that has been utilized to target enrollment and retention issues with proven success since 2005 [11]. The first major retention issue that projects target is the lack of a well-defined student support system. Numerous studies have shown that students who are involved in small groups retain more than students who work alone [12]. Isolation of a student from his or her peers can cause stress beyond that imposed by an already formidable field of study. At the beginning of each school year, the Solar Boat and Moonbuggy projects fall under the responsibility of a group of students who opt to become members of the University's EVP Team. Students from any background and major are invited to attend, though historically teams have primarily consisted of students from the Engineering Technology department. All EVP teams are primarily student-led, with assistance provided by the faculty advisor and numerous university staff members. Team organization and operation relies on a modified and proven Peer-led, Team-learning (PL-TL) model [11,12,13], where students support and mentor each other throughout the course of the project.

The PL-TL model is designed to supplement classroom lectures by requiring students to engage in active group learning. The group environment can prove more conducive to learning than a classroom setting, as the students feel less pressure to provide correct answers or "textbook solutions" to the problem at hand [13]. The benefits of group activities to STEM-student retention have been well-documented. A study conducted by Tinto [14], [15] reported that student involvement in group learning environments promoted student retention. Tinto writes that "For some students...the collaborative environment of the learning community provided a safe place, a smaller knowable place of belonging, in which they were valued and in which they discovered they could learn."

The Solar Boat Team members as well as the Moonbuggy Team members collaborate on all decisions throughout the lifetime of their annual project. Together, the students brainstorm how they want to build their boat and conduct all of the necessary research, construction and testing in preparation for the annual competition. As per the PL-TL model, the more senior students lead the inexperienced students [6]. The students often develop strong relationships with their teammates, which in turn encourages them to continue the pursuit of the project and their degree. Such academic and social support networks are crucial components of student retention [14].

The second problematic issue that all EVP projects seek to mitigate is the suppression of creativity and ingenuity.

Often in STEM disciplines, much value is placed on achieving single, correct answers with no additional credit awarded for innovative approaches to problem solving [4]. Students are often discouraged from recognizing or exploring alternative approaches to problems. The fear of being wrong or labeled as "unusual" can lead to excessive reliance on stilted or rote problem-solving skills [4], which may likely discourage some students from remaining in or entering the engineering technology field. Conventional and uncreative behavior is directly counter to the qualities desired of future innovators, especially those expected to tackle some of the most important engineering technology issues ever encountered in modern human history.

## Student Outcomes

One of the main goals of the Experimental Vehicles Program is to engage students. Most undergraduates are only exposed to general classroom curricula. However, the EVP provides an outlet that allows students to gain hands-on experience. It also supplies the students with valuable knowledge concerning the process involved in completing complex engineering projects. Due to the fact that the students are peer led, they are able to be involved in every aspect of the vehicle's creation, from conception to design to actual manufacturing. The competition teams are comprised of undergraduate students that are recruited across many disciplines in order to incorporate as much diversity into the program as possible. These students typically represent the STEM concentrations; however, this extracurricular program is open to any discipline. The teams on average are not gender specific and are representative of multiple nationalities. This ensures that the students will be able to learn from collaboration, while at the same time preparing them for a future job in which communication will be the key to being fully understood.

Annually, EVP members are comprised of about 30% females and 70% males. Of these, generally the demographics break down roughly to 50% white, 20% African American with the final 30% made up of other nationalities. Each vehicle team is comprised of approximately twenty students that are split up into smaller teams that will each focus on specific aspects of the vehicle. Each team has constant access to a graduate student mentor as well as faculty advisors. With such a readily available support system, the students are able to explore their skills in ways they may not have been able to before.

Giving undergraduate students the opportunity to gain hands-on experiences through extracurricular lab-based projects has proven to be critical and should be considered as an obligation to all universities [16]. The skill set acquired

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through the EVP projects at MTSU helps students involved after graduation to secure high level jobs. For those students that get involved in the EVP program as a freshmen or sophomore, and take on leading roles in project design and manufacture, have reported back to EVP faculty that their initial base salary is \$20,000-\$25,000 more than their contemporaries. Due to the real-world experience, the EVP students report that their employers are paying them as if they have 2-3 years of job experience; this is an incredible edge in the very competitive job market. Past EVP students have been able to procure careers with Nissan, Tennessee Valley Authority (TVA), NASA, GM, and other automotive industries. Moreover, on numerous occasions, the companies that have hired an EVP graduate have contacted EVP faculty mentors asking if any other students are graduating with the same experience and expertise. This is an incredible statement to MTSU, the EVP and its students.

## Conclusion

The Experimental Vehicles Program in the Engineering Technology Department at Middle Tennessee State University promotes innovative thinking through applied research projects. These projects are novel and inspirational. They allow students to gain important hands-on experience, while giving them the encouragement to harness their engineering prowess. Classroom discussions have some limitations in the goal of exposing Middle Tennessee State University students to the challenges that they will face in the real world. The Experimental Vehicles Program (EVP) at MTSU is an innovative, award-winning program that supplements classroom discussions and provides students with a forgiving environment in which to test the skills and knowledge they acquire at MTSU.

EVP projects not only enhance classroom learning but also teach students things they ordinarily wouldn't learn in a class, such as organizational, leadership and communication skills. Perhaps most importantly, the projects give students a taste of the engineering team environment, and help foster effective working relationships.

The EVP experience has not only provided a valuable way for MTSU students to gain essential hands-on experience, but also has led to higher retention and graduation rates. In addition, out of the many students that participate in EVP projects, 95% receive highly desired jobs upon graduation. As further testament to the fortitude of this program, the Tennessee Board Regents awarded the program the Academic Excellence Award in 2012. Because of the competitive nature of each event that the EVP participates in, students must use cutting-edge technology and design methods in order to field the very best entry possible. Often,

these projects serve as rolling test beds for the latest innovations in various technical fields and are accompanied by a great deal of student research.

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## Biographies

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