AC 2011-272: INTERCOLLEGIATE DESIGN COMPETITIONS AND MTSU'S MACHINE SHOP: KINDLING ENGINEERING TECHNOLOGY-STUDENT CREATIVITY & CONFIDENCE

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Dr. Foroudastan's academic experience includes teaching at Tennessee Technological University and Middle Tennessee State University in the areas of Civil Engineering, Mechanical Engineering, and Engineering Technology. He has actively advised undergraduate and graduate students, alumni, and minority students in academics and career guidance. Dr. Foroudastan has also served as faculty advisor for SAE, Mechanical Engineering Technology, Pre-engineering, ASME, Experimental Vehicles Program (EVP), and Tau Alpha Pi Honors Society.

In addition to Dr. Foroudastan's teaching experience, he also has performed extensive research and published numerous technical papers. He has secured over one million dollars in the form of both internal and external grants and research funding. This funding has come from several organizations, including the Tennessee Department of Transportation and the National Science Foundation. Dr. Foroudastan is the faculty advisor, coordinator, and primary fundraiser for EVP teams entering national research project competitions such as the Formula SAE Collegiate Competition, the Baja SAE Race, the SolarBike Rayce, the Great Moonbuggy Race, and the Solar Boat Collegiate Competition.

For his concern for and dedication to his students, Dr. Foroudastan received MTSU awards such as the 2002-2003 Outstanding Teaching Award, the 2005-2006 Outstanding Public Service Award, and the 2007 Faculty Advisor of the Year Award. He received the Excellence in Engineering Education award and Faculty Advisor Award from Society of Automotive Engineers (SAE). He was also nominated for the MTSU 2005 and 2009 Outstanding Research Award. Dr. Foroudastan has also won many College of Basic and Applied Science Awards including the 2004 Outstanding Service Award, the 2006 Overall Excellence Award, the 2006 Excellence in Publications, and the Top Publisher and Presenter three years in a row (2002-2004). In addition to this, Dr. Foroudastan also reviews papers for journals and conference proceedings of ASEE, ASEE-SE, and ASME, and he has been a session moderator for several professional conferences. Dr. Foroudastan has also served on committees at the department, college, and university levels.

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Intercollegiate Design Competitions and Middle Tennessee State University's Machine Shop: Kindling Engineering Technology-Student Creativity & Confidence

Abstract

Educators often face the daunting task of finding ways to encourage creativity and confidence in students. Limited time and pre-defined course objectives can further burden this task. Hands-on activities in the laboratory courses that often supplement basic science classes are, inarguably, beneficial as they can reinforce classroom concepts and instill students with confidence in both their knowledge and abilities. However, that confidence is often limited to the constructs of the textbooks used in the specific courses, and laboratory work may not always challenge or excite students. Engineering educators face additional challenges in creating hands-on experiences for their students. The nature of engineering endeavors in terms of cost and development-time can limit abilities to create meaningful engineering- laboratory courses. Additionally, faculty-led and course-driven laboratory experiences are often designed around textbook concepts that do not necessarily expose students to challenges similar to those they may encounter in their future professional endeavors. This may leave students questioning the relevance of their education to "the real world" at the end of their courses. At Middle Tennessee State University (MTSU), the Engineering Technology (ET) Department has overcome these issues through the partnership of its student-led, extracurricular Engineering Vehicle Program (EVP) and the student-managed campus machine-shop laboratory.

Students, excited by their participation in EVP projects and by their access to state-of-the-art engineering tools, enthusiastically participate in machine shop activities. The machine shop provides a learning environment similar to that found in traditional science-based laboratories without the similar structure that can, potentially, stifle creativity. Students are naturally motivated to perform well at EVP design competitions, and the machine shop provides means for them to develop unique solutions for design and manufacturing challenges.

This paper will explain MTSU's approach to inspiring engineering creativity and confidence in its engineering technology students through utilization of an on-campus machine shop and participation in national intercollegiate design competitions. The success of this program has been realized through both increased enrollment and graduation rates in its Engineering Technology Department.

Introduction: A Need for Laboratory Experiences That Do Not Stifle Creativity

Laboratory courses often supplement basic science classes in high school and college. The hands-on activities provided in laboratories can challenge and excite students in a ways not achievable through traditional lecture-style teaching. Working in laboratories gives students opportunities to explore scientific concepts while applying knowledge gained classrooms. These experiences not only reinforce textbook ideas, but also instill students with confidence in both their knowledge and abilities. The benefits of laboratory activities and their contributions to engineering-student retention have been well documented. A study conducted in 1998 suggested that as few as 8.5% of students leave engineering studies due to poor academic performance.[1] An oft-cited study conducted by Vincent Tinto reported that student involvement in learning communities promoted student retention. Tinto writes that, "For some students, especially those who, in the past, had struggled in school, 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."[2] In subsequent evaluations, Tinto also identified academic and social support networks as crucial components of student retention.[3] Laboratory projects can provide students with both learning communities and vital support networks.

Although common in the scientific realms of chemistry and biology, it becomes more challenging to provide relevant laboratory courses to engineering students. Due to the, typically, complex nature of engineering endeavors, it can be both difficult and cumbersome to provide full-scale, real-world problems for classroom investigation. In typical engineering classrooms, single aspects of larger systems are investigated out of context or with the application of complex assumptions. Isolating one concept at a time is usually necessary for teaching fundamental engineering concepts but risks blinding students to the applicability of what they are learning to larger, more complex systems[4]. The same pedagogy may be used for engineering students in the laboratory, though it is difficult to focus exclusively on the design or modification of a single component of much larger system. Once adequate instruction occurs explaining engineering theories in enough detail for the application of engineering concepts to real-world simulation, there is often inadequate time and funding available.

Additionally, course-led laboratory experiences can be very structured and do not necessarily encourage students to develop creative approaches to scientific problems. Creativity is often highly valued in courses pertaining to arts and literature. In mathematics and engineering, however, value is placed on achieving single, correct answers. No additional credit is given for innovative approaches to problem solving. Creativity expert, Sir Ken Robinson, calls this focus on singular approaches "the tyranny of common sense."[5] Students don't recognize, or explore, alternative approaches to problems because they are working them exactly the way the problems have always been worked. This rigid approach to problem solving is compounded by students' fears of answering questions incorrectly. Students' grades often control their scholarship funding or financial aid, their abilities to take additional courses, their abilities to graduate, and their abilities to find employment after graduation. The general fear of being wrong or fear of receiving poor grades can prevent students from "thinking outside the box." A study conducted at Ohio State suggests that stress, such as that induced due to worrying about academic performance, can further dampen creative thought.[6] Stress and fear of failure can lead to stilted and rote problem solving skills. If failure occurs, or grades are lower than expectations, students lose confidence in their abilities to find successful solutions, and this further inhibits creativity. The challenge to colleges and universities then becomes finding ways to incorporate the benefits of the laboratory experiences that simulate real-world engineering experiences into engineering technology programs without hampering creativity. MTSU has successfully tackled this challenge through the utilization of its on-campus machine-shop laboratory and its Experimental Vehicles Program (EVP$_{MT}$).

MTSU's Approach to an Engineering Laboratory Experience

The Experimental Vehicles Program at MTSU (EVP_{MT}) encompasses four extracurricular engineering design projects: NASA Moonbuggy, SAE Baja, Formula SAE, and ASME Solar Boat. These projects encompass the design, budgeting, construction, and testing of experimental vehicles by student-led teams for entry into national and international collegiate competitions. Each student-designed and student-built vehicle must meet specific requirements outlined by the competition sponsors. For example, the NASA Moonbuggy must complete an obstacle course under the constraints that it be completely human powered collapsible into a four cubic-foot volume for transportation. Engineering endeavors, such as this, can be very complex, and there are rarely singular solutions to any given problems. Solutions must equitably balance multiple known constraints and variables, while compensating for unintended consequences. A particular design challenge may have several optimal solutions. Because of this, it is beneficial for engineering projects, like those in the EVP_{MT}, to have indefinite life-spans. Students both create new designs and develop novel approaches to earlier designs to meet the same design requirements. The multi-faceted approach gives them more insight into new engineering-design issues and the impact of changes to existing designs. This learning experience is not possible in university courses that are only one-semester long or in industry where expediency is essential. The implementation of the EVP_{MT}, therefore, addresses the need for real-world engineering technology learning environments and activities. Students may participate in EVP_{MT} as part of a capstone elective, but many participate on a voluntary, extracurricular basis.

When MTSU implemented its EVP_{MT} in 2004, the two-fold intent was to generate interest in the Engineering Technology (ET) Program among high school and community college students and to provide students with hands-on learning applications for their engineering studies. Figures provided by MTSU's Office of Institutional Effectiveness show marked growth in ET enrollment following the implementation of the EVP_{MT} (Figure 1), confirming that the program intent has been achieved.[10, 11]

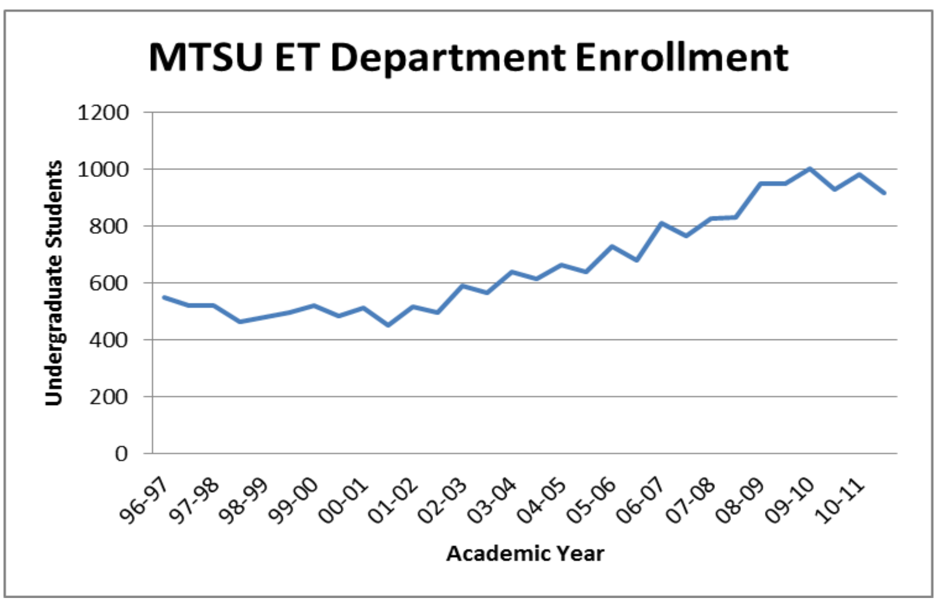


Figure 1: Growth in ET Enrollment
(Source: MTSU Office of Institutional Effectiveness)

Additional benefits have been realized, as well. First, graduation rates in the Engineering Technology Department, as tracked and reported by the MTSU Office of Institutional Effectiveness, have increased 75%[10,11], which means that retention rates have also improved. Second, the utilization of the peer-managed machine-shop laboratory has provided a stress-free environment for students to creatively work through EVP_{MT} challenges.

The Machine Shop Laboratory at MTSU

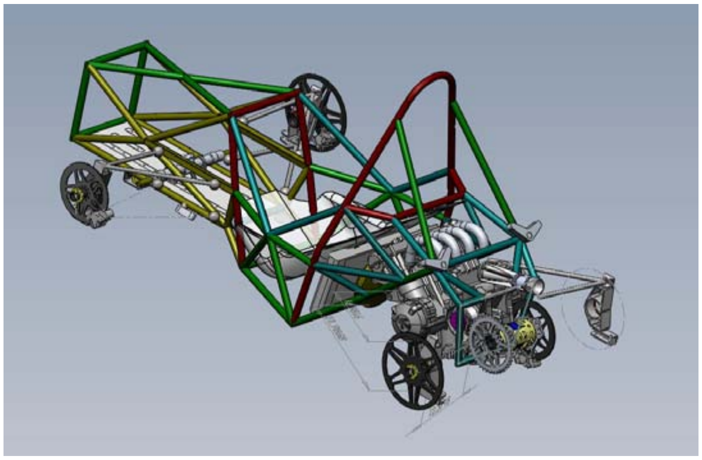
The heart of the EVP_{MT}, the on-campus machine shop, allows students to develop their vehicle projects from the initial stages of research and design to the final stage of physical reality. Approximately 80% of EVP_{MT} project components are constructed inside the ET machine shop, with the remaining 20% occurring elsewhere on campus. The shop serves as an "engineering laboratory," allowing students to apply their knowledge, skills, and abilities to tangible projects. Housing the majority of ET's physical resources, the laboratory contains standard workshop tools and state-of-the-art equipment such as a Sratasys 3-D prototype machine, a Universal Laser System, and a Fadal 4-axis Computer Numerically Controlled mill. Students also have access to the latest computer software, including CAD/CAM and SolidWorks.

A student programs the Fadal CNC mill to fabricate wheels for the Moonbuggy.

The variety of equipment available in the machine shop allows students to manufacture most of the parts needed for their vehicles while providing them with opportunities to learn practical machining techniques, quality control, tolerancing, and design for manufacturability. The ability to manufacture most of their designed components on campus has provided substantial cost-savings, allowing the teams to effectively manage limited funding resources. For example, by manufacturing all the NASA Moonbuggy wheels in the machine shop, the team saved an estimated $3,000.

Student Benefits from the EVP_{MT} Machine Shop

The hands-on experience in the EVP_{MT} machine shop laboratory takes engineering students beyond classroom learning. Vehicle-concept development requires the students to apply and utilize their classroom knowledge of engineering principles and apply them toward design completion in a research and development-type setting. While constructing the vehicle, the students gain competencies in assembly knowledge and design analysis. Such experience helps students gain a deeper understanding of how engineering principles combine to form a complete system[5].



A SolidWorks screenshot of the 2009 Formula SAE vehicle. Each component of the vehicle is individually modeled before being combined to form a complete system.

The development of the vehicle from idea to product gives the students a first-hand view of the consequences of different design methods. They begin to understand design-for-manufacturability concepts, such as tolerance-stack-ups, which can be difficult to grasp in a classroom setting. As a result of physical or fiscal restraints, not every design drawn on a computer can be assembled successfully or easily. Through hands-on development of their projects, students glean appreciation for the development of a design from the concept-phase through the final production. This teaches the students how to respect both ergonomic and equipment constraints—a fundamental consideration for all engineers in the workplace. More importantly, the relaxed and peer-led environment allows students the freedom to develop alternatives to their design-for-manufacturability challenges. Nobel laureate Samuel Beckett aptly stated, "Ever tried. Ever failed. No matter. Try again. Fail again. Fail better."[9] Driven, not by fear of failure or fear of receiving an undesirable grade for a course, students are free to creatively explore obstacles in their designs, developments, and assemblies. They are less likely to seek textbook solutions to laboratory hurdles when exposed to challenges similar to those they may encounter in their future professional endeavors.

A custom-designed sprocket (left) and differential (right) created and manufactured by students on the Formula SAE team.

Students working in the machine shop gain experience in technical activities that are closely related to their future career goals. The practical employment experience gained helps students determine if the field of engineering technology is right for them. The experience is also valued by employers, who seek competent and well-rounded graduates with a working knowledge and thorough understanding of classroom concepts. Some students participating in the EVP_{MT} have even benefited from their time in the machine shop prior to graduation. Due to the machining skills he learned in the machine shop, one student was able to secure a well-paying job within the local community while continuing his studies.

The engineering laboratory encompasses more than the application of engineering concepts and development of physical skills. The engineering laboratory is also a life-learning experience.

Hands-on laboratory provides students with opportunities to develop knowledge outside of the classroom and instills a sense of independence and responsibility for their own learning. It inspires their desire to learn and generates curiosity towards developing new skills. The EVP_{MT} team members become personally invested in their work, feeling a sense of excitement, ownership, and pride. Because the projects are a group effort, the development of communication skills and trust is essential[5]. Although the teamwork component can be heavily emphasized, individuals also learn how to work independently, since each person must carry their own weight to ensure the project's success, and there is a sense of accountability within the team dynamic when one, or more, individuals are not meeting their responsibilities. As data suggests, students who feel a sense of personal contribution and responsibility toward the success of the team and who receive academic, social, or personal support through a team environment are more likely to remain enrolled in and graduate from college.[3] Team members must hone their skills for innovative negotiation among interdisciplinary and multi-cultural team members. Additionally, students develop methods to creatively balance academic, social, and project time requirements, a skill necessary for successful integration in the work force.

Innovation and creativity are essential skills for students working on the EVP_{MT} projects and for practicing engineers, as no structure, machine, or process is designed to be built without future maintenance or refinement. It is natural for new challenges to arise during the process of construction and during the product's lifetime. For an experimental vehicle project to be successful, the students must learn to think on their feet. Each team member exercises creativity when encountering the inevitable obstacles that arise before an important deadline or during a competition. This valuable learning experience helps prepare the future engineers for the pressures they can expect to face in the industry.

Through machine shop endeavors, students develop their abilities to

- successfully manage an engineering project
- work effectively within a team
- work with confidence individually
- find creative and innovative solutions to design, management, or production challenges

The student teams provide collaborative environments through which students can find value in their input and receive peer-mentoring for academic challenges.

Moonbuggy team members test-driving their vehicle.

Conclusion

Science fiction author Ray Bradbury once said, "Don't think. Thinking is the enemy of creativity. You simply 'must do' things."[9] Working in an unstructured, peer-managed environment removes the academic pressures students may feel in course-led laboratories while nurturing creative approaches to engineering challenges, teamwork, communication, and management. Personal desires to succeed at intercollegiate design competitions motivate students to find innovative solutions to challenging design hurdles. The on-campus machine shop has provided MTSU with a way to offer an engineering laboratory experience. The engineering laboratory, together with the EVP_{MT}, provides a beneficial dimension to undergraduate engineering technology education. The opportunities and unique experiences available through the EVP_{MT} have attracted many new students into the MTSU's ET Department. The hands-on and competitive nature of the projects have helped improve retention and graduation rates among participating students. By fostering effective communication, leadership, and project management skills, graduating students with EVP experience are better prepared to enter the workplace as successful and productive engineers.

The competencies gained through their work on EVP projects in the machine shop benefit students in three primary ways. First, self-imposed competitiveness and work in a faculty-free laboratory provides a unique environment for students to seek innovative and creative approaches to engineering technology problems. Second, students gain confidence in their engineering abilities in nurturing, peer-led environments which fosters a sense of ownership and interest in their education. Third, students are provided with resume-worthy discussion items for post-graduation interviews, which can increase confidence in their potential for future professional successes. The realization of these benefits has been substantiated through both increased enrollment and graduation rates in MTSU's Engineering Technology Department.

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