
AC 2011-2717: ACTIVE LEARNING THROUGH SAE BAJA COMPETITION

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Active Learning through SAE Baja Competition

Introduction

Active learning is described as finding ways of engaging students in the learning process to improve the results of the process. Active learning has become popular as an organized methodology in engineering education in the last few years. It is an important approach to prepare better engineers. Competitions, course projects sponsored by industry, capstone projects, laboratory exercises simulating real-life scenarios, case study and film reviews, service and undergraduate research projects as well as internships and cooperative experiences are all considered as examples of active learning in engineering education. Engineering students learn more effectively and retain better by dialoguing with self and others, observing, and doing. Role play, project management, marketing, developing team interpersonal and technical skills are only a few of the perks actively engaged students enjoy¹. This paper focuses on learning by taking part in competitions, and especially the Society of Automotive Engineers (SAE) Baja Competition.

The SAE Baja competition requires engineering students to design and build a single-seat all terrain or off-road vehicle². There are three different regional events for this annual competition in North America, not all of them requiring the water event. At the three-day regional competitions teams are judged through the following stages:

- First through inspection for aesthetics, safety, manufacturability, serviceability, structural integrity, ergonomics, and their cost and design report for the development process.
- The second element of the competition is based on performance events such as acceleration, maximum speed, braking, climbing, weight pulling, and maneuverability.
- The final component is a four-hour race over an off-road course including hills, moguls, jumps, sand, mud, and possibly water.

All teams must follow the SAE Baja rule book while designing, and use an identical 10 HP 305 cc Briggs and Stratton engine. Since all the vehicles need to use the same engine, chassis, drive train, suspension, braking, and other design factors become important for winning this competition.

At the author's institution the SAE group took two years to prepare for their first competition. Since then two more cars have been built with mixed results. Main improvement has been the development of a better car with less weight and improved steering and speed. In the last two years mechanical and manufacturing engineering students were involved in the effort. Challenges up-to-date have led to strong learning experiences in vehicle design, especially in computer-aided design (CAD) and mechanical design, manual and computer-numeric controlled (CNC) machining, welding, and assembly operations. The students also gained invaluable experiences in leadership, team building and interpersonal skills, communications, project management with planning, scheduling, and resource management, and marketing as they promoted their project in search of sponsors. This paper draws a clear picture of the active learning experience of the SAE Baja team at the author's institution while presenting the positive and the negative.

College Level Competitions and the SAE Baja

There have been many competitions intriguing and challenging engineering faculty and students including the ones detailed below. Others are not within the reach of smaller schools such as Defense Advanced Research Project Agency (DARPA)'s Grand and Urban Challenge³. Some others like SAE's Formula Series⁴ may require greater resources compared to the ones below.

- The Institute of Navigation (ION)'s Robotic Lawn Mower Competition will be held June 2-4, 2011 in Beavercreek, Ohio⁵. The objective of the competition is to design and operate a robotic unmanned lawnmower using navigation to rapidly and accurately mow a field of grass.
- NASA's 18th Annual Great Moonbuggy Race will be held April 1 - 2, 2011 in Huntsville, Alabama, at the U.S. Space & Rocket Center. Each Moonbuggy will be powered by two students, one female and one male for travelling over a half-mile simulated lunar terrain course including craters, rocks, lava ridges, inclines and lunar soil. The winning teams will be those having the shortest total times in assembling their moonbuggies and travelling the terrain course⁶.
- 2011 ASEE-SME Design and Manufacturing Competition will be held June 26-29, 2011 in Vancouver, British Columbia Canada during the ASEE Annual Conference⁷. The objective of this competition is to design and fabricate a novel colonoscope to successfully enter a simulated and covered colon through its anus, and then navigate the device to find and extract a polyp locate at cecum end of the ascending colon.
- The Direct Digital Manufacturing Tech Group of the Society of Manufacturing Engineers (SME) is seeking entries for its annual Design for Direct Digital Manufacturing (DDM) Competition⁸. The 2011 (to be held during Rapid 2010 May 24-26, 2011 in Minneapolis, Minnesota) competition encourages engineering students to use their creativity and design a product to be, or be part of, a system utilizing DDM in features. The product must be able to be used in another assembly, and it will need to be fabricated mainly using DDM processes.

Requirements for the Competition

The annual competition calendar starts with the registration and release of the annual rule book. The registration process is on-line and happens in Fall Semester in October. The registration in the 2009 competition was \$300, only to be raised to \$1000 in 2010. Another important part of the registration is to associate each student member and team advisor with the team registration. With the registration and the release of the annual rule book, the teams start studying the rule changes and look for potential sponsors. A sponsorship package is developed by the team members and approved by the Institutional Advancement of the school as well as the prospective sponsor list. Support from the home institution is always sought as well.

After the annual design is determined, a comprehensive cost and design report need to be submitted in the Spring semester in February and April respectively for a June competition. If the competition is in April, design report is due in March. Both reports require details such as value of labor cost during the fabrication of the vehicle as well as receipts or an accurate design

analysis to justify the selection of the tubing for the roll cage and rest of the vehicle for safety. Deadlines are firm and points are deducted from the overall score of the team.

The Design and Fabrication Process

The design process is capped with the preparation of a comprehensive design report. The report includes an abstract, introduction and conclusion sections as well as the design for chassis, body, cockpit (Figure 1), steering and power train, tires and wheels, electrical, and suspension and braking systems. The safety features are also critical and included in the report for roll cage padding, harness and arm restraints, kill switches, lights and alarms, and power train guards. The authors of the report are identified at the beginning of the report. Some teams conduct Finite Element Analysis (FEA) for their vehicles to improve the performance and safety of vehicles.

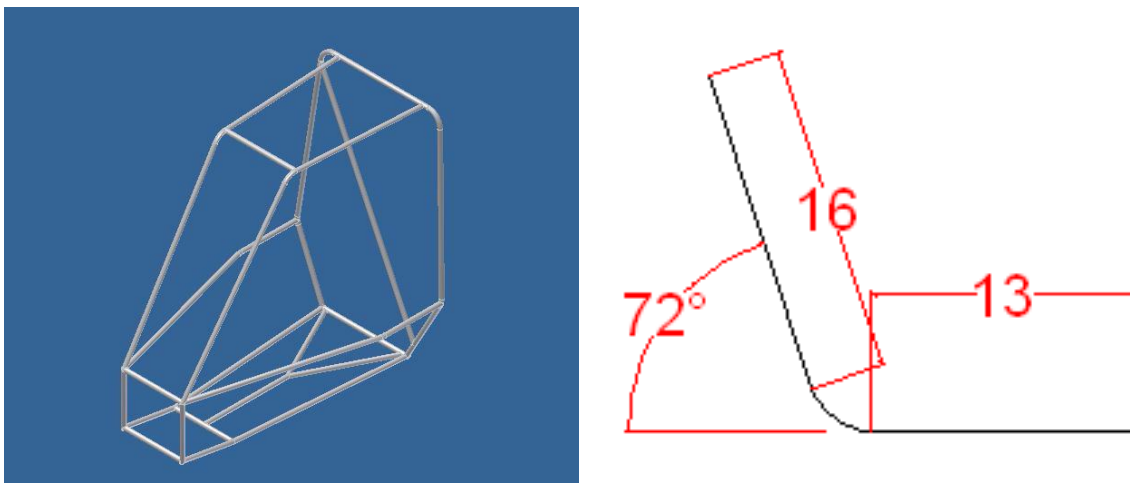


Figure 1. INVENTOR design model of the roll-cage as well as 2D tubing design sections ^{9,10}

With the completion of the design or most of the design the team starts the fabrication of the vehicles. A few problems arise during the fabrication forcing the team to alter the original design for certain reasons such as manufacturability, weight reduction issues, or availability of parts. The design changes are documented to be presented during the competition. Fabrication and assembly are very labor intensive. However, students are able to turn this cumbersome experience into a fruitful one in terms of learning. Various manufacturing processes including tube bending and cutting, TIG and MIG welding, joining through adhesives, fiberglass panel fabrication, and various sheet metal forming and cutting processes are applied. Assembly of the systems has to happen twice, once before the painting, and once again after the painting. Figure 2 is illustrating the welding process while Figure 3 depicts the roll cage fabrication stage. Figure 4 shows a more completed vehicle including its power train, electrical, and braking systems.

As the team completes the manufacturing and assembly processes, organizational preparations need to be done for the trip to the competition. These include arrangement of housing accommodations, transportation of the team and the vehicle as well as completion of official forms for the SAE for the space requirements during the competition. As a last step, welding

samples are prepared and testing at the laboratories. These samples will be collected during the inspection at the competition.



Figure 2. Welding the cage



Figure 3. Almost completed roll-cage plus



Figure 4. Reassembly is almost complete



Figure 5. 2009 and 2010 vehicles

The Competition and Conclusions

After the completion of the vehicle and brief testing, the team heads to the competition. Once the registration is complete, the team needs to go through an engine inspection, a design presentation, as well as full vehicle inspection and brake testing. After passing these steps, the teams are eligible to compete in the performance events and the endurance race.

The lead author has been working with this BAJA team for almost three years in addition to helping the original team with the manufacturing issues four years ago. Even though the competition results have been mixed for this team with the best vehicle obtaining the worst results, the learning experience proves to be strong. Students have developed to be better engineering candidates and so far only one student's grades have suffered due to being heavily involved in this endeavor. Most of the members continue to perform well in their coursework even though they spend countless hours in the laboratories. The interest in the program has recently peaked. The 2009 team had 5 active members with only 4 attending the competition while the last year's team had 9 active members with 6 attending the competition. This year the original team had collected about 30 names while some of the students are not active due to being freshman.

This engineering program has recently been accredited for another six years with almost no issues. Major part of the program's continuous improvement is based on outcomes assessment and accomplished through FCARs (Faculty Course Assessment Reports). However, an extracurricular activity like this also contributes to the growth of the students. Thus, it needs to be assessed as well. The following list includes the ABET-driven basic engineering outcomes and relation of some BAJA experiences to them. These prospective engineering graduates:

1. Have an ability to apply knowledge of mathematics, science, and engineering. The BAJA members apply rules of geometry in chassis and overall vehicle body design, follow strength of materials in selecting tubing for the roll cage and other load bearing sections of the vehicle.
2. Have an ability to design and conduct experiments, as well as to analyze and interpret results. The BAJA members prepare and test welding samples as well as interpret the results obtained from these welding tests.
3. Have an ability to design a system, component, or process to meet desired needs. It is evident that the students design and build a system with structural, mechanical, electrical, and hydraulic subsystems working in harmony for effective operation to accomplish a goal. Various customized part design and development also need to be carried out.
4. Have an ability to function on multidisciplinary teams. The BAJA team included students from Software, Mechanical, and Manufacturing Engineering programs, as well as sub-teams working with different goals such as chassis design, mechanical design, or manufacturing.
5. Have an ability to identify, formulate, and solve engineering problems. The students need to resolve multiple problems in steering and suspension design in addition power-train to build a competitive vehicle. Strength of the vehicle is also critical

- during the endurance event. The students in the past built Kevlar supported body panels to prevent piercing.
6. Have an understanding of the professional and ethical responsibilities. Each designer knows the ramifications of their designs since a fellow student will be operating the vehicle. Each team member also functions appropriately knowing that each information or data generated or recorded by them has to be the most accurate not only for safety but also for ethical responsibilities.
 7. Have an ability to communicate effectively. The BAJA team members need to communicate verbally in the meetings and in the laboratories. They also may need to write memos and e-mails to the rest of the team or to third party entities in addition to preparing cost and design reports to be reviewed by the SAE officers. At the competition, multiple presentations are also required.
 8. Have the broad education necessary to understand the impact of engineering solutions in a global societal context. Automotive engineering is probably one of the most globally influenced fields in all engineering fields. The BAJA team members are interested in automotive design and are indirectly involved in understanding of global societal impact of the automotive field. On the other side, the competitions held in the summer are filled with foreign teams allowing students to experience different ways of design and operation.
 9. Have recognition of the need for and ability to engage in life-long learning. The BAJA students will be engaged in the automotive field even they do not work in it. The overall experience has improved practical ability of some of the best theoretical students, also making them more interested in automotive engineering. This will encourage them to stay engaged in the area and continue to learn, especially with the help of being more practical and confident.
 10. Have knowledge of contemporary issues. The BAJA team members receive two periodicals, one in Automotive and the other in Aerospace Engineering. These periodicals and other SAE resources keep students updated in their field.
 11. Have an ability to use techniques, skills, and modern engineering tools necessary for engineering practice. CAD/CAM/CAE, CNC or manual machine operation, welding, plasma cutting, and various other current technologies are utilized and practiced by the team.

In addition to the basic outcomes listed above, the team members get a good dose of practical manufacturing education even though they may be enrolled in a different program. Manufacturing engineering students also improve their backgrounds. Material science and engineering, manufacturing processes and assembly operations, tool engineering, planning, strategy, and control as well as marketing for raising money are some of the major areas where students build strong competencies after being involved in this valuable program of learning by doing. The overall project is a real-life project for accomplishing a goal and is immersed with great laboratory experiences.

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