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Introduction

To design, build, and race a successful Society of Automotive Engineers (SAE) Baja car, a new SAE club faces a variety of challenges. In 2008, a new SAE student chapter was formed at NMU and the author became the faculty adviser for this club. This paper presents the insights gained from the author's first four years of developing a new SAE program at NMU.

The primary purpose of the SAE club at NMU is to help engineering students develop the knowledge and skills necessary to become competent engineers. Since many students join this club in their freshman year, their engineering knowledge and manufacturing skills must develop at a rapid pace for them to make a solid contribution to the team. The SAE Baja project provides ample opportunity and motivation for students to engage in problem-base learning. Once the initial challenges of facilities and funding are met, the adviser can focus on coaching and facilitating this problem-based learning.

At the outset, acquiring the facilities and funding needed to build a race car is one large challenge facing a new SAE club. Adequate shop space, tools, equipment, and supplies must be acquired quickly; thus initial funding must be available if these assets cannot be reallocated from existing resources. After the startup costs, funding is needed to purchase parts and supplies for a new car each year. Sponsors and partners from industry can play a vital role in meeting these annual funding needs.

Another primary challenge facing an SAE Baja team is developing teamwork and leadership within the student organization. In the past three years at NMU, several student leadership and organization styles have been tried, and the positive impact of good organization and leadership has been significant.

Several obstacles have been overcome in the first few years of NMU SAE club's existence and the club has been developing into both a successful student organization and a good setting for problem-based learning.

Description of Baja SAE Project

The Baja SAE project is described by SAE[1] as follows. "Baja SAE consists of three regional competitions that simulate real-world engineering design projects and their related challenges. Engineering students are tasked to design and build an off-road vehicle that will survive the severe punishment of rough terrain and sometimes even water.

The object of the competition is to provide SAE student members with a challenging project that involves the planning and manufacturing tasks found when introducing a new product to the consumer industrial market. Teams compete against one another to have their design accepted for manufacture by a fictitious firm. Students must function as a team to not only design, build,

test, promote, and race a vehicle within the limits of the rules, but also to generate financial support for their project and manage their educational priorities.

All vehicles are powered by a ten-horsepower Intek Model 20 engine donated by Briggs & Stratton Corporation. For over twenty-five years, the generosity of Briggs & Stratton has enabled SAE to provide each team with a dependable engine free of charge. Use of the same engine by all the teams creates a more challenging engineering design test."

To design and manufacture a complete vehicle (see Figure 1) in accordance with a collection of stringent requirements[2] is a challenging task for an adviser to facilitate in the initial years of participation. In the first year of the NMU BAJA SAE program, much time was spent obtaining the basic equipment and tools needed to manufacture the vehicle. Once the facilities were in place, the focus shifted to specific design issues and team organization.

Figure 1 – SAE Baja Vehicles in Action

Physical Space, Tools, and Equipment

The shop space necessary to manufacture a Baja SAE vehicle includes floor space for machining equipment (mill and lathe), welding equipment, vehicle fabrication and assembly, and secure storage. At NMU, an 864 square foot fabrication and assembly space is also used as a general purpose shop space for other student activities, so an adjacent 256 square foot storage space is needed to secure the vehicle, parts, materials and tools.

NMU has a fully equipped machine shop with both manual and computer numerically controlled (CNC) mills and lathes. Other tools needed include a CNC and handheld plasma cutters, bench top and handheld grinders, a tubing bender, a welder, a hydraulic press, and a complete set of mechanics tools. A team can function without the CNC equipment, but using CNC equipment provides another learning experience for students.

For travelling to races, an enclosed 16 foot trailer has been found the best way to transport the car, tools, and equipment. In addition, a 3000 watt portable generator is needed to power tools and welders at races. At the outset, much of the equipment was already available in the manufacturing lab at NMU, and other items such as a trailer, generator, and various tools were borrowed or rented.

Sponsorships

Funding for the NMU SAE club comes from several sources. The university provides the shop space, equipment, tools, and enclosed trailer. The university also maintains a student travel fund that has provided travel monies for one national event and one regional for each of the past three years.

The annual cost of the Baja SAE program at NMU has ranged from $9,000 to $15,000. The cost to transport the vehicle, equipment, and a team of six students ranges from $2,000 to $6,000, depending on the distance to the event. The cost of parts and materials to building a Baja SAE vehicle has ranged from $6.000 to $8,000. The entry fee for a national race is $1,000.

The funding to build the vehicle has been raised from cash donations and donation of parts and materials. The financial and moral support of sponsors has been a key ingredient to the birth and growth of the Baja SAE program at NMU. Polaris Industries provides parts to all university SAE clubs at a small fraction of retail cost. Each year Team Tech Racing donates a new seat belt and harness, neck restraints and arm restraints to the NMU team. Local industry has provided cash donations ranging from $4,000 to $6,000 each year. NMU has also contributed $2,000 per year.

The additional benefit of relationships with local industry is that engineers and experts in areas such as suspensions and clutches are available to share their expertise with students.

Club Membership

SAE club membership is open to all NMU students, but the majority of students are enrolled in the 4-year Mechanical Engineering Technology program. Membership ranges from 6 to 12 members in a wide variety of majors including: MET, Electronics Engineering Technology, Technology Education Nursing Major, English, and Entertainment and Sports Promotion. The team has a recruitment drive at the start of each semester, with invitations to attend meetings announced in engineering technology courses. Dedicated “pizza supper” meetings for potential new members have been tried, but is more effective to simply invite interested students to attend the regular Monday, Thursday, and Saturday meetings, so they can see the club in action.

Team Building and Organization

The need for effective teamwork and organization became readily apparent after the first year at NMU. In the first year the team was very loosely organized, without any defined student leaders, thus by default the adviser took on the role of leader and organizer. This organization model might work if the adviser has the time available to take on this role, but it was very

difficult for an adviser with full-time teaching responsibilities. The lack of organization resulted in poor project management, and friction amongst the team members. Team members did not have clearly stated roles in the project, so the responsibility for completing tasks and coordinating schedules was unclear.

In the second year, the author required the team to elect officers, and the students began to take on specific roles. The president was tasked with running meetings and managing the project schedule. The vice president assisted the president. The combined secretary and treasurer handled correspondence, tracked expenditures, made travel arrangements, and organized the tools and equipment.

In the third year, the student leadership became more highly defined. On the 3-day return drive from the 2010 race, the team had the opportunity to discuss and establish goals and design ideas for the upcoming year. With the author facilitating, the team established a goal of placing in the top 30 % in the 2011 race. IN addition, a list of vehicle performance improvements was developed for the 2011 car, and design changes needed to achieve these improvements were brainstormed. It was helpful to discuss features which were observed on other teams' cars during the 2010 event.

The NMU team is fortunate in that most of the team from 2010 returned for the 2011 race season, and have been able to build upon their experience. At the beginning of the school year the author met individually with each team leader to discuss the role each could take on and the details of what would be necessary to fulfill that role. This organization structure has resulted in much better project management and a more effective use of time. The team president has taken on the role of project manager with a passion, and he possesses a very effective leadership style. The vice president's role is lead designer. The high level of commitment and energy that these two students provided made a tremendous difference in the third year.

To foster team spirit and to instill an ethic of community service, the NMU SAE club volunteers in the local community each year. The club maintains 6 miles of hiking and skiing trails each fall, and in the winter club assists at a Boy Scout Merit Badge day held on the NMU campus. The club also has social gatherings twice each semester, either a dinner or club outing, just to help foster good relationships within the club.

Vehicle Design and Problem-Based Learning

The Baja SAE program is an excellent opportunity for problem-based learning. Students are motivated each year to build a car that performs better than the previous year's car. This motivation often results in students spending 10 or more hours per week on this project.

It has been helpful to break the project into three component groups; frame and roll cage, front suspension and steering, and rear suspension and drive train. Student leaders were appointed to each of these component areas.

Component leaders at NMU have taken on the role of component research and design. One desired performance improvement was a shorter turning radius. One student leader researched

vehicle suspensions, and wrote a report describing how to design for issues such as Ackerman steering geometry, roll center, wheel scrub, and tire contact patch. He then designed a front suspension and steering system that has been built on the 2011 vehicle and it radically improved the ability of the vehicle to turn and negotiate rough terrain. Another student leader investigated gear box design, and designed and built a prototype gear box. Still another investigated chain case design and designed and built a prototype chain case.

All of these projects were valuable problem-based learning experiences. The students met with their advisor occasionally for direction and short tutoring sessions, but for the most part, the learning was self-directed.

Organizing the Design Process

The process used to design a new vehicle starts with setting goals for performance improvements. The day after a race, the team meets to identify car performance improvement goals for the next car. As the adviser, the author places some limits on the design space so that the team has a realistic expectation of what can be accomplished in one year based upon our resources.

Once goals are established, team brainstorming sessions are used to develop component design concepts, combining prior knowledge and knew knowledge from race experience, then students select concepts to focus on and research.

The deadline for final design is late September, and the deadline for manufacture is the end of January so that the vehicle is ready to compete in a regional winter race in mid February.

Educational Outcomes

Preparing students to become competent design engineers in the manufacturing industry is a fundamental goal of the Mechanical Engineering Technology (MET) curriculum at NMU. The SAE Baja club helps achieve that goal by provided students with a realistic design and build project.

The benefits of the Baja SAE experience at NMU can be measured in observing how individual students have grown in their ability to design a product that can be manufactured. This is the only design and manufacture experience of this magnitude available to Mechanical Engineering Technology students at NMU, the only other experience that compares is the two semester capstone design project.

Measurements of how much students benefit from the experience have included conversations with graduating team members and their employers. Team members that were actively engaged in this typically comment that this project has helped them gain confidence in their ability to design and manufacture a product. Former NMU SAE club members also note that their contributions to the SAE Baja project are a main point of conversation in interviews with

prospective employers. Employers of NMU Baja SAE members have been enthusiastic in their praise for how quickly these students become productive team members in industry.

Another measurement of the benefits the Baja SAE project is that 100 percent of the MET students on the NMU Baja SAE team have graduated and obtained desirable engineering jobs. Considering the current economic condition of Michigan, this is a good indication of the benefit of Baja SAE.

In the future, surveys of NMU MET graduating seniors and their employers will include questions to measure the benefit of the Baja SAE for recent engineering graduates.
One unexpected outcome is that the Baja SAE club at NMU has been active in recruiting students to the MET. Baja SAE club members provide tours and show off their vehicles and shop for visiting high school students. SAE Baja members also enhance the universities relationship with the local community by engaging in community service activities with the Boy Scouts and trail organizations.

Summary

The Baja SAE program at NMU has been an effective tool for teaching product design and development in a realistic setting. The project motivates students to learn about design and manufacturing, and it teaches the value of developing effective working relationship in teams. The program takes a good deal of effort to get started and a great deal of support from within and outside the university, but after the first three years at NMU the initial effort is reaping many rewards.

Bibliography

1. SAE , "About Baja SAE", http://students.sae.org/competitions/bajasae/about.htm.

2. SAE, "Rules and Important Documents", http://students.sae.org/competitions/bajasae/rules/.