AC 2012-3714: LESSONS LEARNED FROM STARTING AN SAE BAJA PROGRAM IN A SMALL LIBERAL ARTS COLLEGE

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Lessons Learned from Starting an SAE Baja Program at A Small Liberal Arts College

Abstract

This paper provides summary of lessons learned from starting an SAE Baja program at a small liberal arts college. For a small engineering program like ours, the notion of a SAE Baja team to be formed and financed was a distant one. But a series of events happened in the 2008/2009 academic year that prompted the birth of the college's first ever SAE Baja team. It was quite a journey for all involved. We started from scratch with no experience and little resources. The learning curve was steep during the first year, and there were crisis moments during the second year. And now we are on our journey of a third year.

It was set up as a two semester senior capstone design project since its start. We soon realized that it was not all vehicle dynamics that we had to deal with, but also team/group dynamics. Lessons were learned in building a successful team and the importance of team work, individual accountability and communications. From a technical standpoint, we achieved some major milestones in vehicle development in a short period of time. For suspension, we went from using an existing ATV suspension, to a student designed independent front and rear suspension. For transmission, we went from a Yamaha dirt bike manual transmission to a Continuous Variable Transmission (CVT), all in a span of two short years. From community engagement standpoint, we were able to pull all local resources we could find and experienced some selfless help from other collegiate teams. Tips are shared on many aspects of the project, from how to get a team started, to how to manage the senior capstone design.

Introduction

SAE Baja USA consists of three annual 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[1]. The team project shall progress from the conceptual design phase to a complete functional vehicle which meets all of the safety, performance, and other criteria outlined by the competition sponsors[2].

SAE Baja project proves to be an effective tool to enhance student learning in a variety of ways. There are extensive literatures on this topic. Sirinterlikci and Kerzmann indicated that a SAE Baja project can serve as an active learning tool for undergraduate students[3]. Foroudastan

expounded on the benefits of peer-led team-learning that comes with SAE Baja projects[4]. Reimer, Lawrence and Abro noted that competitive activities such as Baja could help nurture the entrepreneurial mindset in students[5]. Hoff and Davis pointed out that the SAE Collegiate Design Series can provide valuable hands-on experience for undergraduates[6]. Novoselich and Dillon explored the unique dynamics and benefits of creating two student teams instead of one to further motivate students to excel, in the context of a large engineering program[7]. Marlor shared his experience serving as a faculty advisor to the SAE Baja team, especially from advising the SAE club perspective[8]. In this paper, we will share our experience working with a small pool of students from multiple disciplines on a SAE Baja project, and the unique challenges we faced in the context of a small liberal arts college. More literature review will be conducted within the body of the paper when a specific topic is to be discussed.

How it got started

What we found out through years of teaching mechanical engineering students is that many relate well to automotive examples because they had experience working with cars. That hands-on knowledge help facilitate a linkage between engineering theory and engineering practice. The first author had many years of experience working in the automotive industry prior to the start of his full time teaching career at the college. Naturally, when he joined the faculty of the college in fall of 2008, he started to use automotive examples in teaching mechanical component design and engineering mechanics. Students were gravitated to his story telling. At one point, he gave them a lecture on automotive steering system and introduced the Ackermann angle concept. One student was so intrigued by this topic that he came to the instructor's office after class and continued to ask questions on how the Ackermann angle works. From interactions like these, the instructor sensed a special interest among this class of students in automotive engineering and design.

The ABET accredited BSE program at the college has a total enrollment of about 185 engineering students, as of fall of 2011, encompassing six concentrations – civil, mechanical, electrical, computer, chemical and interdisciplinary engineering. Typically a senior class for mechanical engineering concentration has about 5-12 students. The college had been participating in Solar Splash[9] competition for years. In fall of 2009, several of the engineering seniors would want to try the SAE Baja project. It had never before been done at the college. We had doubts – do we have the necessary resources to support such a project? Do we have the expertise to supervise these students? What does it take to start a program like SAE Baja at a small college like ours? How to do it? None of us had any experience in doing this. But students' enthusiasm eventually won over. In addition to four mechanical engineering seniors, an electrical engineering senior student also joined the team – his hobby was fixing cars. One student on the team had some experience working on dirt bikes. Another student enjoys working with CAD.

Still another was quite gifted in hands-on activities. That was pretty much what we had initially – no one on the team had much clue as to what it would take to make a working Baja vehicle.

Baby steps

Somehow the news that we were starting a SAE Baja project got to one of the college's retired faculty members. He was a chemistry professor and used to serve as a fuel testing expert for the racing community. He hooked us up with the local SAE chapter. We brought our students to one of the SAE local chapter events that year. There we met some local collegiate Baja teams. The faculty advisor of the Grove City College SAE Baja team, Dr. Vern Ulrich, informed us that there was going to be a local Baja competition in Ohio sponsored by Honda. He recommended that we go and observe the competition and learn. We sent two students to work as volunteers. Later they became key members of our first Baja team at the college.

We started to have weekly meetings. One student was good with software, so we assigned him to focus on solid modeling of the vehicle. He was able to obtain a math model of the Briggs and Stratton engine from the internet and started to put a CAD model together. We elected a team captain, who was responsible for coordinating the team members and keeping track of the deadlines required of the team. One student was strong in welding, so we assigned him as the main welder. Another student who had experience working on dirt bikes was assigned the task of designing a transmission. He went home during the break and with the help of a friend he made some modifications to a Yamaha dirt bike transmission to fit our vehicle. The students also needed to do fund raising – some of them started to make cold calls to local companies and sent out letters to alumni and started the solicitation of funds among friends, relatives and family members.

We also tried to get whatever advice we could get from local "experts". We would invite local racing enthusiasts to come on campus and meet with our students. Dr. Vern Ulrich at Grove City College also invited our team to observe their team's practice and gave us valuable advice on how to start the program. Before we finished our first vehicle, he also came to give us tips on how to pass tech inspection, etc. Even though the two colleges sometimes compete for students in recruiting, but the genuine and selfless help Dr. Ulrich provided us was very touching. It shows true sportsmanship. We also experienced the same kind of friendship and sportsmanship at the competitions. We will share some of that experience in a later section of this paper.

Senior capstone design

For a SAE Baja program to succeed in a small college, using senior capstone design project as the "super glue" is a must. One local university that we know of, their engineering program is

about the same size as ours, and they had a couple of years fielding a Baja team. But recently they decided to call it quit and stopped the program because not enough students are committed to it. They were running it like a student club. The students were not obligated to devote more time to the team because they were not getting academic credits. We'd argue that a two semester senior capstone design course is the best way to hold the core of a team together. With this core team in place, other underclassmen would be able to join in. And this would make it possible for the Baja project to have long term success in a small engineering program.

Kim, Morris and Deller documented Bradley University's successful run at SAE Baja using a two semester capstone design course sequence[10]. Since Bradley has a much larger engineering program, the teams were comprised of all mechanical engineering students. One advantage of a small college like ours is that students from multiple disciplines would have an opportunity to work on the same team. They would normally take the same introductory engineering classes together in their first two years of core studies. Then they would branch out into concentration specific courses in their junior and senior years. Of the three teams we had so far, all had an interdisciplinary make-up. The first two years, there were four mechanical engineering students and one electrical engineering student on the team. This year, we have five mechanical engineering students and one computer engineering student, plus two marketing majors from the business school. The two marketing majors are not taking the senior capstone design course (our business school does not have such a requirement), but they get marketing course credits from the business school for helping the Baja team with marketing and fundraising. Obviously this arrangement needs some cooperation from a business faculty.

At the beginning of each fall semester, the majority of the senior class is assigned a senior design project. Each student would have to submit bids for 2-3 projects of their choice and rank his/her level of interest in each. Then the engineering faculty would meet and discuss and assign them projects. Individual faculty advisors would be in charge of each team or individual projects (sometimes for a larger project or projects that are interdisciplinary in nature, we would have co-advisors). The advisor(s) would meet with students regularly to make sure good progress was being made throughout the two semesters. Below is our grading policy:

Attendance at team meetings: 10%

Team work (peer review at the end): 20%

Fundraising: 20%

Technical report: 20% (see detailed requirements below)

Presentation: 20% (This includes a notebook requirement – each student needs to prepare a notebook to take notes in meetings and document their progress working on the

project throughout the year. The instructor will periodically check it and make sure it is up to date. At the end of the year, they need to be turned in so the instructor could grade it)

Competition: 10-20% (this includes both preparing for the competition and actually participation at the competition)

Technical report requirements:

- It should document in detail your work on the SAE Baja project for the two semesters.
- Length requirement: at least 10 pages, typed, double space, font 12, Times Newman. The 10 pages could include graphs, plots, etc. Focus on the things you did. If it is a joint effort, list your percent contributions and the names of the team members.
- Efforts in fund-raising, marketing, PR, organizing, logistics, presentations, etc. all count.
- Detailed recommendation on future work.
- This document should minimize introductory material. It should go directly to the meat of your work. If the work involves a design, you need to elaborate on design goals, design alternatives, the analysis process that leads to the design selection, cost analysis, etc.
- It should have a well annotated reference section at the end of the report showing all the books, articles, personal communications, etc. to properly acknowledge others' work.
- This report is due within one week of the completion of the competition, or if you are not planning to go to the competition, within one week of the end of the 2nd semester.

We will talk more about the presentation component in later sections of this paper.

Engaging underclassmen

It is important to engage under classmen as early as possible in the Baja program. They help maintain continuity in the program from year to year. Stover discussed how the SAE Collegiate Design Series competitions can be incorporated into mechanical engineering curriculum that would give students technical elective credits[11]. For underclassmen, depending on their level of involvement and contribution to the project, we offer them from 1 to 3 credits of independent study that would count towards their engineering elective requirements in the general BSE program.

The first year we had one student who was heavily involved with the construction and testing of the vehicle in the final months and went to the competition with the team. The 2nd year he was

able to help the new team members get up to speed on the project. The second year we had two freshmen and two juniors helping with design work, fundraising and fabrication of the vehicle. Some of them went to the competition with the team. Except one who quit the team to focus on academics, all have returned to the team working with the new members. Currently, we have two mechanical engineering juniors and one sophomore on the team. It is important to assign them some tasks to keep them involved.

Community support and impact

For a small college, it is extremely important to engage the local community to gain access to resources and expertise that are otherwise not available or inadequate for supporting a SAE Baja program, especially during the first few years.

For us, in the first year, a local race car enthusiast provided some metal bending expertise and equipment for us to use. The second year, a local race vehicle shop owner got heavily involved in training our students in using various tools, including vehicle dynamics software, in designing and construction of the Baja vehicle. The students got hands-on learning that was otherwise not available from the college. One of the student's Dad got heavily involved towards the end of the preparation for competition. Being a professional weld inspector, he was able to critique the students' work and provided some hands-on training and help to our students.

The SAE rulebook[2] forbids professionals from being directly involved in a student team. It says in Article 6.1 of the rulebook that "the vehicle and associated documentation must be conceived, designed and fabricated by the team members without direct involvement from the professional engineers, faculty or professionals in the off-road and racing communities". When we contacted SAE and asked what "direct involvement" would mean, the answer we got was quite vague and it seems limited involvement of racing professionals as coaches is okay as long as the students are learning something.

An SAE Baja program is an excellent recruiting tool to help draw students. Since the start of our Baja program, the college marketing staff has been working with us to write articles on these students' achievement and experiences that appeared in alumni magazine, student newspapers, and on our college website. It also became a natural attraction for potential students and families during their campus tours. We showcased the Baja project in a recent STEM (Science, Technology, Engineering and Mathematics) day event on campus where our students explained to our guests what they had done and what they had learned.

Another benefit of having a SAE Baja program at the college is that it helps engage the alumni base. Many alumni, including non-engineering majors, contacted us and pitched in ideas of

improvement to our design. Through these connections, some students get interview opportunities for internships, and some of these alumni were invited back to attend on campus events organized by the Institutional Advancement staff to enhance connections between alumni and current students. The alumni were glad they had something to give back to the college, and the college benefitted from their volunteer work and increased giving. One engineering alumni, who is a retired vehicle dynamics engineer from Ford, offered our students free training on some basic vehicle dynamics terminology and concepts. He also critiqued the students' initial design this year. The engineering department organized an industry advisory focus group meeting in fall of 2010. Many of the advisors that attended the meeting came through our connections to the local SAE community. They offered valuable advice on curriculum improvement and a range of other things to enhance our engineering program.

Fundraising and budgeting

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[1].

Fund-raising is a major hurdle for a startup team, because everything needs to be built from ground up. And most things cost money. The first year, we spent around $10,000 in total, including travel expenses. From our experience, that is about the minimum that is needed to kick start a new Baja program. For us, the student union at the college sponsored the travel cost of about $3,400; the engineering department pitched in around $3,800 in registration fees and purchasing of raw materials, tools, etc. The rest came from alumni and corporate/individual donations. The second year, the students redesigned everything except the roll cage. We ended up spending over $15,000 that year, way over our budget. In hindsight, we could have saved $2,500 on a new air shock. An air shock would be nice for rock crawl though – we were able to achieve a top 20 ranking in this event last year.

"Where there are new transgressions, there are new laws". In our first year, the students were very cost conscious and very responsible in spending. So it made our advisors' job easier and there was no need of special rules on spending control. But in the second year, sometimes the students would spend beyond our means and that resulted in over-spending due to our lack of control. So this year from the beginning, we laid down detailed budget rules for the students to follow. They now need to get proper approval before any significant expense is incurred.
To better control the budget, this year we offered our students some training on project management and budgeting. One of the Board of Trustee members of the college, who is a professional business consultant, volunteered to give our students two sessions of such training on campus. He would train our students on how to use a budgeting spreadsheet in Excel to do

detailed analyses of projected expenses in each category and help them come up with goals and strategies for fundraising.

We also invited some business majors to help with fundraising and marketing. For the first time, the team put together a sponsorship packet. This is needed for seeking corporate donations. We involved the engineering secretary to help coordinate the editing and printing of the packet and other fliers and pamphlets. Coordination is also needed with institution advancement staff at the college – they need to approve the sponsorship packet and make sure our alumni do not get double mailings of our fundraising letters, as we have other student teams on campus, such as the Solar Splash and Steel Bridge teams, who also need to do fundraising.

From our interactions with the various teams at the competition, some colleges/universities have big corporate donors, but most teams have tight budgets to work with. And that is part of the challenge of the competition – to produce the best vehicle with minimum cost. The lower the cost, the higher the score a team will get in costing category of the scoring. It becomes a training ground for our future engineers so that they will be cost conscious in their engineering work.

Figure 1 Our first year vehicle with a Polaris ATV suspension (center clearance of 12”)

Design challenges

The objective 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[1]. Since we have a small team (5-6 students each of the past three years), and were building the vehicle from ground up, the first year team decided to use whatever parts and components we could find to minimize the number of components that had to be made by ourselves. The team decided to use a Polaris ATV suspension that was purchased on Ebay (Figure 1). We also decided to use a manual transmission instead of a more complex Continuous Variable Transmission (CVT) the first year[12]. Figure 2 shows our first year vehicle. When it came to creating a rendition of the conceptualized design, it was decided that Autodesk Inventor be used. A main reason for using Inventor was it was already available at the college. Later on we found that SolidWorks would offer all SAE Baja teams use of their solid modeling software for free. Subsequent teams used either SolidWorks or Inventor, depending on the skill level of individual student and availability of PC hardware. Figure 3 shows the solid model of part of the vehicle for the first year.

Upon completion of the drawing, construction of the body began. All tubing ends were cut using a steel cut-off saw and notched using appropriate milling machine bits. Bends would be made using a manual ram style bender, and GMAW (MIG) welder would be utilized for all welding operations for the first year[12].

Figure 2 Our first year vehicle in the endurance race

Our goal as a rookie team was to successfully pass the technical inspection and be able to finish all the race events. We were able to achieve those goals in the competition at Bellingham, Washington, in June of 2010. For the 2nd year team, the students decided to revamp the whole vehicle except the roll cage – it was quite an aggressive move by the students, since we only had three seniors on the team. A CVT (Figure 4) was purchased to replace the manual transmission[13].

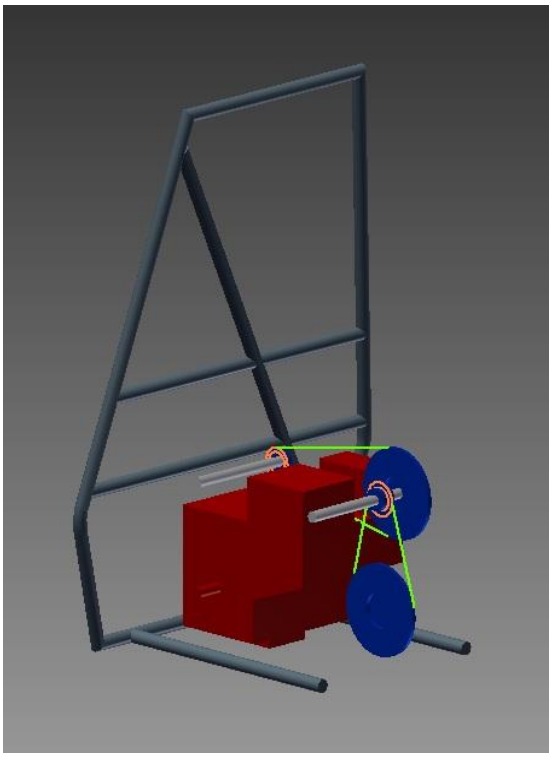

Figure 3 Solid modeling of the vehicle

Figure 4 Polaris P90 CVT used on our 2nd year vehicle

A much lighter and better tuned independent front and rear suspension were designed and fabricated by this group of students with help from community advisors. We were able to pass

the technical inspection a lot easier than the year before and entered the race with much higher hopes.

Lab space, tool and equipment

It takes shop space to build a Baja vehicle. It also takes a lot of tools and special equipment. Our college provided the team a part of a high bay shop area as a dedicated team work area. It is always a good idea to have a designated tool chest for the team, whether that is purchased by the college or brought in by a student member of the team. Since we have three student teams working on different competition projects pretty much every year (SAE Baja, Solar Splash, and Steel Bridge Design), and they all share the same shop floor, it is critical that each team properly label and store their own tools. The first year our team captain brought in his own tools. He spray painted the handles of his tools so they can be easily identified in case some are misplaced by other students. In the second year, our students found a local race car shop and decided to work on the vehicle over there. The shop owner was very helpful and provided his shop space for free. He also made his shop equipment and tools available to our students. That was where the students found that a TIG welder is much better suited for the Baja project. Compared to a MIG welder that we used in our first year, a TIG welder is a lot more versatile and could weld thinner metals, even aluminum. To reduce the overall weight of a vehicle, one would want to use thinner steel tubing and aluminum parts as much as possible. The disadvantage of having the students work off campus is that it could lead to inadequate oversight of the project. So the 3rd year we decided that the college purchase a TIG welder and move the "operation" back to our shop on campus. We took advantage of the heavily discounted prices for parts and equipment from companies such as Lincoln Electric, Polaris, and Dana that our students successfully negotiated with for corporate sponsorships.

Competition logistics

Transportation of our Baja vehicle to the competition site was a major challenge for our first team. What we found out was, the college insurance does not cover the towing of a trailer. To save cost, we rented a cargo van and stuffed the Baja vehicle sideways into the van after taking off the four wheels. That year we had to travel across the country for the competition, as sites close-by already had been fully booked. It was a major chore to take off the wheels before we leave and then re-assemble them at the competition. The 2nd year one team member borrowed a trailer and truck from a friend and a family member and we were able to tow the vehicle without college's insurance coverage (a risky move that we would not recommend). This year, after the intervention of a Board of Trustee member, the college finally agreed to add trailer to the insurance coverage for student teams.

It would also be helpful to bring a desktop drill press to the competition as the students most likely will need it to drill holes through head of fasteners for self-locking safety wiring. Other things most teams bring to the competition include portable/retractable canopy and lawn chairs to keep out the sunshine or rainfall, a portable generator and work lights, TIG/MIG welders, etc. Most teams spent significant amount of time at the competition site fixing their vehicles per tech inspection feedbacks, etc.

Interactions among teams at competition

Hallbach and Gordon from Rochester Institute of Technology (RIT) deliberated the benefits of using SAE Baja competitions to help students gain a global perspective[14]. The students would not only have opportunities to interact with students of various international teams at competitions held in the US, but also at international competitions if they travel to places like Brazil, South Korea and South Africa. Foroudastan and Hyde discussed the value gained through encouraging international students on campus to get involved in SAE Baja and Formula One clubs at Middle Tennessee State University (MTSU)[15]. Our campus is not as diverse as either RIT or MTSU and we do not have nearly as many international students. And our Baja program is not big or strong enough to allow our students to go overseas to compete.

But one thing we all can experience is the camaraderie of the competition teams at domestic sites, including some teams from other countries. The first year we had no trailer of our own to tow the car to different sites (that year the organizer had two sites – one for tech inspection, the other for dynamic and endurance events). The students made some quick friends with other teams and one team agreed to put our vehicle on their trailer to ship it to the other site. One international team from Venezuela asked us for some spare parts and our students were glad to share with them. At the end of the competition we exchanged team t-shirts. Throughout the competition our team members mingled with this Venezuela team and learned how a team from another part of the world operates. It was quite a learning experience for our students as most of them had never stepped on the soil of another country. In short, the Baja project helps our engineering program achieve the ABET outcome of educating engineering students with a global perspective.

Crisis management

Like in any team sport, we quickly realized that it was not all vehicle dynamics that we had to deal with, but also group/team dynamics. A variety of personalities come together on one team, and when under the pressure of time, personalities could clash. Sepahpour and Chang discussed in details the structures, elements and strategies of team building in competitions like SAE Baja[16].

Goff and Terpenny contended that the real challenge of a Baja project is not of mechanical engineering expertise, but one of team guidance and management[17].

The first year, we were fortunate to have a strong student leader on the team who was elected a team captain. Electing a team captain or co-captains is the way to go in most cases unless the advisor is a strong leader him/herself and had the time to micro manage the team. The student who was elected captain was an excellent student and is a self-starter. He is quite dependable in terms of following through on deadlines and deliverables and setting up work schedules, etc. It is a big contributing factor to the success of any Baja program – a strong leader in the first year, whether that is a student or a very hands-on advisor. It is also a good idea to list a staff member who is in charge of the shops and tools to serve as a co-advisor to the team.

Figure 5 Our 2nd Team in Peoria, Illinois, 2011

As faculty advisors, we had to sometimes get involved and resolve issues. The first year team once had an argument on which church to go to on the Sunday when they were on the way to the competition (it was a cross country ride). One student was adamant about going to a specific denominational church, while many other team members would not care too much about denominations but would rather find a church along the way and not waste time getting off the main road in order to find a specific church. The team captain told us about the crisis situation and we had to come up with some ideas of helping the students reach a compromise. The 2nd year, at the competition, one student was overly aggressive in the endurance race and wrecked a

suspension part. The team member who was mainly responsible for designing and fabricating the vehicle got visually upset. He was ready to throw in the towel and quit the competition. The other team members would not want to quit because the race was not over and there was still time to fix the vehicle and continue to race. But the student who put his heart and soul into the suspension believed that any quick fix would only compromise the integrity of the suspension and would cause further damage to the vehicle that he deeply loved. The debate became quite heated, with both sides not understanding what the other side was coming from. Just at that time, a student from another college/university went by and took notice of the argument. He looked at the damaged parts and offered advice on how to fix it. Eventually the team voted in favor of the fix in order to continue in the competition. Another student who throughout the year had at times been quite passive on this project suddenly became a strong leader in a crisis situation like this. He rallied the team together and made the quick fix and the team entered the race again. We were able to finish 41st out of about 115 vehicles (Figure 5). That was a big improvement over the previous year, when we were 55th.

Post-competition follow up and outcome assessment

The first year, since we had no prior experience supervising such projects, we made a mistake of assigning the students grade before the competition. The competition was in June, and the end of the semester was in May. At the competition, one student was not happy with the grade he received for the two-semester senior design course. It was kind of awkward to have to explain to the student about the grade he received while he is still working on the competition vehicle. So the next year we postponed the grade assignment until the competition is over. This gives them some incentive to continue to work hard and improve their grade beyond the end of the semester.

Their course grade is based on:

(1) their performance when working to prepare for the competition
(2) their performance at the competition
(3) their written report on lessons learned from the competition and recommendations for future work

This proves to be an effective and fair way to evaluate their complete body of work while keeping their morale high towards the end. It also provides them an opportunity to reflect on what they had learned at the competition and be able to document it. Obviously, if the competition happens in April or early May before the semester is over, this is not an issue. It would always be wise to include their performance at the competition as part of their senior design course grade to make them accountable until the end. Some special circumstances might arise when some students could not participate in the competition due to obligations such as attending a wedding or starting a new job, etc., or in some cases if they do not get a grade at the

end of a semester it would disqualify them from certain graduation awards at the college. In these situations, the advisor needs to handle it a little differently. But in most other situations, including competition performance as part of their grade would only encourage students to actively participate and learn in the whole process. Actually, by going to the competition the students would have so much fun that they would not want to miss it anyways. Many of the students expressed their excitement in one way or the other that the few days at the competition were a highlight of their four or five years of college education experience.

As Wang pointed out[18], the capstone design course is the most important course in the whole engineering curriculum for outcome assessment as it covers almost all of the ABET outcomes A through K. For outcome assessment during the first and second year, we have been using faculty evaluations as our main tool to evaluate each student's performance. Each student will have two opportunities to present their work – one at the end of their first semester of senior design to present the scope and initial plan of their project, the second at the end of the second semester to report on their progress on their work. The students' presentations are all videotaped. Engineering faculty from different concentrations (civil, mechanical, electrical, computer, environmental, chemical engineering) provide feedback on both technical content and presentation delivery for each individual student, even though the presentations are organized according to groups. For example, the Baja team may be allocated 20 minutes and each of the 3-4 students have to give a coherent presentation as a team but also each present some aspects of his/her own work.

For the 3rd year, we decided to add a peer-review at the end of the competition to better gage each individual's performance in the area of team work, as indicated in the grading policy mentioned earlier in this paper. In the future, we might consider having students do some self-evaluations, or have external stakeholders such as employers, industry advisory board members, or other students to provide additional direct assessments, as suggested by Wang[18].

Conclusions

SAE Baja is an excellent activity for students to apply what they learned in their four years of engineering education to solving a practical problem. They need to plan and execute plans in all phases of the product development and production cycles. They also need to demonstrate economic viability of the project by doing cost analysis and marketing presentations. It is a good situational learning tool to hone their team work and leadership skills. It is technically challenging and in the meantime involves many other aspects of a modern engineering enterprise, such as people skills. We hear comments from some Baja team members that this year long project was a consummation and highlight of their undergraduate education experience. They learned so much more than what they would normally learn from a classroom

setting. Significant challenges are still present year to year, as each year's team is made up of new team players with different skill sets and personalities. Fund raising is still a perennial challenge.

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