2006-1751: USING THE SAE COLLEGIATE DESIGN SERIES TO PROVIDE HANDS-ON TEAM PROJECT EXPERIENCE FOR UNDERGRADUATES

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Learning experiences that are "hands-on, minds-on" are often considered to be more successful at achieving knowledge transfer than the traditional college lecture approach. The Society of Automotive Engineers (SAE) annually conducts a series of design competitions, where students from Universities throughout the world compete. Student teams are provided with a detailed set of rules that provide guidance into the competition events and point structure, and base engineering and safety requirements. Students have less than one year to design and build a vehicle used in the competition. All competitions require the students to present their designs and vehicle to a group of professionals working in the particular field. Further, the vehicles, which are designed and manufactured by the students, are then used to compete in a series of dynamic events.

To evaluate the short- and long-term benefits of these competition projects and other SAE student activities, a survey was developed and distributed to recent graduates of Kettering University. For example, do the alumni of these competitions feel that these events helped them to gain better employment opportunities and faster career advancement? Both alumni who had these experiences and alumni who did not have these experiences were surveyed.

This paper provides a brief introduction to the SAE design competitions along with the results of the alumni survey.

Introduction

Starting in the early 1960s, engineering education shifted away from engineering *practice* and more towards engineering *science*. Declining enrollments and shifting priorities caused universities to reduce program length. In order to accomplish this, many programs reduced application oriented courses and laboratories.[1] This has resulted in a gap between what universities are teaching, and what engineers are expected to know in industry.[2] Engineers in industry spend much time working on complex system integration, yet few engineering graduates understand this process.[3] Reference 2 adds "the state of education in this country, especially in science, engineering and technology, has become a matter of increasing concern to many of us in American industry."

The new ABET requirements support a renewed emphasis on teaching the practice of engineering. In part, this reform was undertaken in order to help academia to become more responsive to the needs of industry. By working to emphasize engineering practice, engineering programs are actually working to meet ABET requirements. However, meeting ABET requirements is now not the goal in and of itself, but simply a measure of how well engineering programs are meeting the needs of industry and their students.

In order to meet the needs of industry, Universities must place a renewed emphasis on teaching the *practice* of engineering. In order to teach the practice of engineering, students must be challenged to study the complex interactions of real engineering systems. Further, students must be exposed to professional standards and organizations, governmental regulations, team dynamics, and societal concerns. In short, students must be afforded the opportunity to *practice* engineering, learning how to apply the underlying scientific principles to the design of these systems.

The challenge for engineering educators is to be able to accomplish this task in a four year curriculum without radically reducing the scientific content. Fortunately, the Society of Automotive Engineering (SAE) offers students the opportunity to practice engineering through various intercollegiate design competitions.

Automotive competitions are a good fit for Kettering University students as many come to Kettering because of the university's automotive heritage and their desire to become automotive engineers. At Kettering University, participation in SAE is optional. Students who are actively involved can enroll in Independent Research courses and may select topics for their Senior design class that relate to the competition vehicles. Most students get few or no course credits and work on these projects as an extra-curricular activity.

Description of SAE Collegiate Design Challenges

Currently, SAE offers assortment of different engineering challenges, ranging from airplane design, off-road vehicle design and race vehicle design. The authors of this paper will focus on the following challenges: SAE Baja, SAE Clean Snowmobile Competition, and SAE Formula Design.

These challenges were designed to attract a variety of students with differing interests-off-road durability, environmental concerns, and racing. All of the competitions share a common vision: to encourage students to work in teams to design, build, describe and compete using their own vehicles.

Student participants get an opportunity to apply principles they are learning in school to solve real engineering problems. Further, students gain insight into the complexities involved when working within a team trying to solve a challenge within tight time and budgetary constraints. These types of challenges serve to motivate the students to dig deeper into their engineering education in order to solve these very real problems.

Finally, these challenges help to draw students into engineering professional organizations such as SAE where they begin to learn to take an active role in their engineering profession. Many of these projects do result in Professional publications and presentations.

For each of the competitions, student teams are provided with a detailed set of rules that provide guidance into the competition events and point structure, and base engineering and safety requirements. All competitions require the students to present their designs and vehicle to a group of professionals working in the particular field. Further, the vehicles, which are designed and manufactured by the students, are then used to compete in a series of dynamic events. Students have less than one year to design and build a vehicle used in the competition.

While the teams are not required to be multi-disciplinary, many teams recruit students from various backgrounds to help with the diverse requirements of these challenges. At Kettering University, most of the students are mechanical engineers; however students from Electrical Engineering, Computer Science and Management are highly recruited by the teams. Further, even the students studying Mechanical Engineering have a diverse background. Some of the students are 'gear heads' and others are pure academics who don't know which end of a wrench to hold. Some are very organized and others work best at deadlines. Successful teams find ways to work with these differences.

These competitions are further described below.

SAE Baja

The SAE Baja Competition is held annually at various locations and draws large numbers of Universities from throughout the world. The object of the competition is to provide SAE student members with a challenging project that involves the planning and manufacturing tasks found in introducing a new product to the consumer industrial market. Each team's goal is to design and build a prototype of a rugged, single seat, off-road recreational vehicle intended for sale to the weekend off-road enthusiast. The vehicle must be designed to be safe, easily transported and maintained. It should be fun to drive and be able to negotiate rough terrain in all types of weather without damage. An example of a Baja vehicle in action is shown in Figure 1.

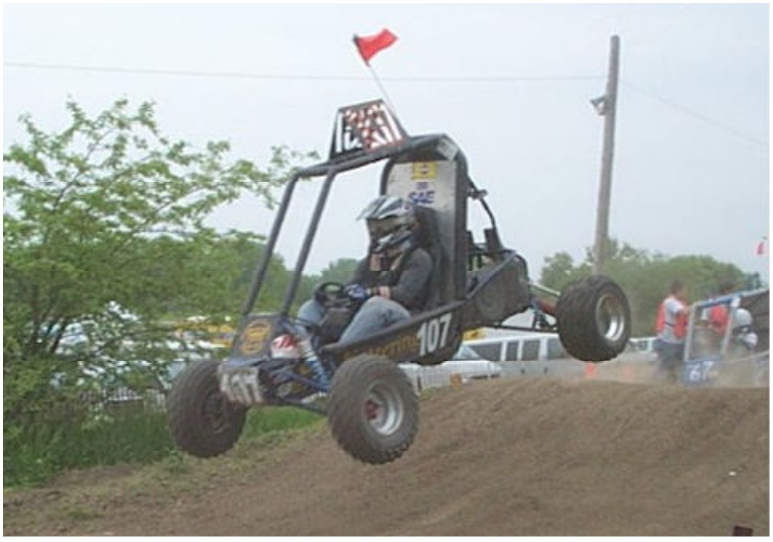

Figure 1. The Kettering University Entry into the 2004 SAE Baja Competition.

Baja vehicles are judged in two different categories: static events (which include a sales presentation, an engineering design review and a cost analysis) and dynamic events (speed, traction, maneuverability, durability and other events). It is significant to note that the static design judging is usually handled by practicing engineers, most of whom are employed in the off-road industry.

SAE Clean Snowmobile Challenge

The Clean Snowmobile Challenge requires engineering student teams to modify a snowmobile in order to reduce exhaust and noise emissions, and improve fuel economy while maintaining or improving upon the performance of the snowmobile. The intent of the competition is to develop a snowmobile that is acceptable for use in environmentally sensitive areas such as our National Parks or other pristine areas. Each year the rules change somewhat to keep the competition fresh. For example, in some years, the students are competing against a control snowmobile that is powered by a two-stroke engine. For 2006, the competition added a new category: zero emission snowmobiles in addition to the reduced emissions category.

The reduced emissions snowmobiles are expected to be much more environmentally acceptable. The intent of the competition is to design a touring snowmobile that will primarily be ridden on groomed snowmobile trails. These snowmobiles must be quiet, emit significantly less unburned hydrocarbons and carbon monoxide than current production snowmobiles, without significantly increasing oxides of nitrogen emissions. Further, the modified snowmobiles are also expected to be cost-effective and comfortable for the operators to drive. A photograph of an entry in action is shown in Figure 2.

Figure 2. Kettering University's Winning Entry in Action during the 2002 Competition.

The Zero Emissions snowmobiles are special purpose vehicles designed for use by research scientists studying the environment in the Arctic. Some of the chemical constituents under study are measured in parts per billion and exhaust emissions from vehicles used on site can skew the research results. Range and performance have always been extremely limiting factors limiting the development of commercially available models. Recent advancements in battery and motor technology may make it possible to develop Zero-emissions vehicles capable of transporting personnel to more distant satellite camp facilities. This would allow access to areas previously accessible only on foot.

Events for both categories include emission testing, acceleration, hill climb, cold start testing, noise measurement, fuel economy, durability & range, and both oral and written design presentations.

Formula SAE

This intercollegiate event draws in excess of 100 Universities from around the world. This competition challenges teams of university undergraduate and graduate students to conceive, design, fabricate and compete with small, formula style, autocross racing cars. Teams typically spend eight to twelve months designing, building, testing and preparing their vehicles for the competition. A photograph of an entry in action is shown in Figure 3.

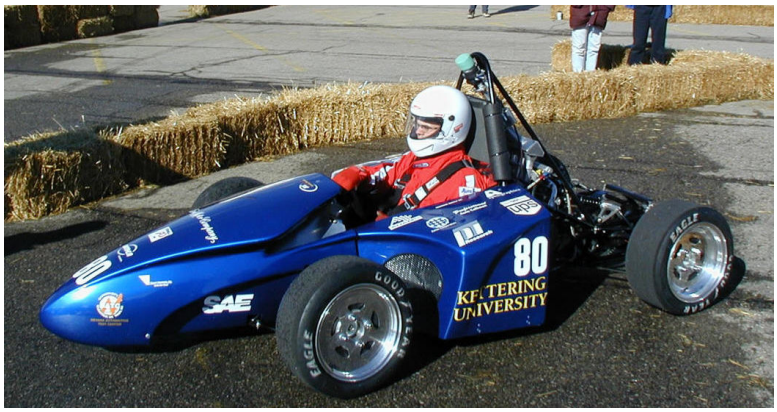

Figure 3 Kettering University's Entry in the Formula Student Competition held in England.

For this competition, the students are to assume that a manufacturing firm has engaged them to produce a prototype car for evaluation as a low volume (four (4) cars per day) production item. The intended sales market is the weekend autocross racer. The car must have very high performance in terms of its acceleration, braking, and handling qualities. The car must be low in cost, easy to maintain, and reliable. In addition, the car's marketability is enhanced by other factors such as aesthetics, comfort and use of common parts. The limited production run and the prototype vehicle should actually cost below $25,000. Each design will be judged by engineers practicing in automotive engineering and compared and with other competing designs to determine the best overall car.

Formula SAE vehicles are judged in two different categories: static events (which include a sales presentation, an engineering design review and a cost analysis) and high-performance track dynamic events.

Assessment

To evaluate Kettering alumni's perception of SAE student activities, a survey was developed and distributed to recent graduates, with degrees in either mechanical or electrical engineering. The students who were selected to receive a survey had graduated within the last six years (2000-2005) and had a valid email address registered with the University Alumni Affairs office. Of the 587 students that were emailed, 148 (25%) responded. A majority of the respondents (81%) identifying themselves as graduates of the mechanical engineering program.

The respondents were nearly evenly divided between alumni that had been student members of SAE (44%) and alumni that had not been student members (56%). A majority of the respondents (72%) indicated that they had not actively participated in SAE activities. This would suggest that roughly half of students that join SAE (and presumably other organizations) did so to 'pad' their resumes – or perhaps they just enjoyed reading the magazine.

Non-Participating Students

Nearly three quarters of the alumni responding to the survey indicated that they had not participated in SAE student activities. The main reasons that they cited for their lack of participation are summarized in Figure 4. The reason most often cited, by far, was a lack of time; either because of class demands (28%) or because the students were involved in other activities (51%). These other activities included Greek Life and family obligations. A significant number of students indicated that they were simply not aware of the opportunities (20%), and others (24%) simply weren't interested.

7. Why didn't you participate in Kettering SAE Activities?

	Response Percent	Response Total
I wasn't interested.	24.1%	26
I was too busy, because of school work.	27.8%	30
I was too busy, because I was involved in other activities.	**50.9%**	**55**
I wasn't aware of SAE activities.	20.4%	22
View Other (please specify)	13%	14
Total Respondents		**108**
(skipped this question)		40

Figure 4. Reasons cited for not participating in SAE student activities.

When asked to provide ideas on how to increase student participation in Kettering SAE activities, these alumni offered the following advice:

1. Offer course capstone credit for participation in the competition projects. For many students receiving credit for the time spent to develop the project vehicles could be justified, if they received course credit for their effort. It would in effect allow them to 'double-dip' on their time commitments. Said one student, "Is it possible to get some minimal credits for fulfilling tasks as part of the team?? Linking activities to some sort of educational credit would allow a higher priority."
2. Integrate SAE activities into classes. Students suggested that integrating aspects of competition design into their courses would be interesting and would serve to help promote SAE participation. For example, one student said, "Correlate engineering/automotive classes with SAE. It would have been nice to do learn heat exchangers [and other topics] and then apply it on an SAE project."
3. Improve advertising of SAE activities. A common complaint among the non-participating students was, "I never really understood what opportunities were available in the SAE program." Many suggestions were offered for improving the advertising,

including doing presentations during freshman orientation and integrating SAE activities into courses.

4. Lower the intimidation factor. Many students indicated that they were reluctant to get involved since they didn't have an automotive background. "It seemed that to be on the team you had to be a diehard gear head". Women seemed to be particularly intimidated by the culture of the team, said one "Let female students know that it's not just a boy's club." One excellent suggestion offered that faculty advisors should stress "the point that even students w/out a technical background in automotive could benefit and could learn new skills, (e.g. working in a multifunctional team, procuring equipment & hardware, managing multiple projects, etc.), all while having a fun learning experience."
5. Promote non-ME activities. "It seems like SAE is geared towards mechanical engineers". The competition projects do tend to be focused towards mechanical skills, so more effort should be made to encourage non-ME majors to participate and to offer other activities, such as speakers.

In reading these responses of the non-participating students, one gets impression that many of the non-participating students might have participated, if some of the barriers had been removed. Said one, "SAE is the one thing I wish I was involved in, but wasn't."

Participating Students

Approximately a quarter of the responding alumni, indicated that they actively participated in SAE activities while they were students. A summary of these activities is shown in Figure 5. The most popular activities include barbeques/picnics (free food), speakers/presentations (a variation on free food, since food is often served) and the various competition projects.

10. Which activities did you participate in? (Check all that apply.)

	Response Percent	Response Total
Barbeques/Picnics	**52.5%**	**21**
Clean Snowmobile	15%	6
Ethanol Challenge	10%	4
FormulaCar	47.5%	19
Formula Lightning	20%	8
MiniBaja	15%	6
Propane Vehicle Challenge	2.5%	1
SAE Mid-Michigan Meeetings	17.5%	7
SAE World Congress	22.5%	9
Speakers/Presentations	50%	20
View Other (please specify)	7.5%	3
Total Respondents		**40**
(skipped this question)		108

Figure 5 Participation in SAE student activities

The participating students were asked about how their experiences with SAE activities affected their perception of the university, their perception of the education program, and the preparation for their careers (See Figure 6). The responses to each question were similar. A third of the

students responded that their participation **greatly improved** their perception/preparation. At least three-quarters of the students' indicated that their perception/preparation was at least somewhat improved by their participation in these activities. This type of response was not unexpected by the authors, based on their many years of involvement with these activities, but they do help to reinforce the importance of this program to both academic and professional communities.

11. How did your participation in the Kettering University Motorsports Program effect the following:						
	Great Help	Some Improvement	Neutral	Slightly Hurt	Really Hurt	Response Total
Your perception of Kettering?	30% (12)	**42% (17)**	25% (10)	0% (0)	2% (1)	**40**
The education that you received at Kettering?	35% (14)	**45% (18)**	18% (7)	0% (0)	2% (1)	**40**
Preparation for your career?	28% (11)	**42% (17)**	28% (11)	0% (0)	2% (1)	**40**
					Total Respondents	**40**
					(skipped this question)	108

Figure 6 Changes in perception due to participation in SAE student activities.

When asked, "What was the best part of being an SAE student member?" the students responded as follows:

1. They enjoyed the community of friends/learners, which is a key ingredient for academic success. "It was a chance to teach my skills to others, or learn together. I got to be part of a team of peers and not part of a hierarchy (like at work).
2. They greatly appreciated the opportunity to put their knowledge to work. Said one student, "It was hands on. I actually got to use some of classroom material. It was an outlet to test my engineering and managing abilities."
3. They enjoyed the opportunity to network, both with the upperclassmen, but also with alumni that had obtained key positions in industry, particularly those that held positions on Motorsports teams
4. They appreciated the job opportunities that came from their participation. "I'm now a ride and handling development engineer because of the work I did while part of Mini Baja."

One student summed up the opportunities nicely. "The hands-on experience (fabrication, CAE) was valuable in my engineering career after Kettering. Functioning on a dynamic team with an aggressive product development schedule better prepared us for the challenges of those in the automotive field. Lastly, many people in the automotive field were either involved with or are familiar with the SAE Motorsports programs. (For example, I work with many former members of FSAE teams...Kettering, LTU, Cornell, Texas A&M, U of M). I believe involvement in the program commends respect in the industry."

When asked, "What was the worst part of being an SAE student member?" the students responded with many of the same issues that had been identified by non-participating students as reasons why they did not participate; but the participating students had a slightly different take on the problem.

1. Lack of time. Finding time to work on the competition projects was always a challenge, and students had to give up other opportunities (like studying) to find time to work on the projects. The final product was not always as good as the students hoped, because of the shortage of time. One student pointed out an additional problem created by this lack of time. "Less experienced members were sometimes pushed out of the way. People who don't know what they are doing cause damage to equipment and don't produce useable results. In the effort for short term results we may have severely damaged long term prospects."
2. Lack of credit. Simply put, the students that worked on the competition projects felt that they were learning as much, if not more, than want they were learning in their academic classes. Receiving academic credit would go a long way to helping them justify their time commitments.
3. Mechanical Engineering bias. One said, "If you were a mechanical engineer, SAE was great because you were working with many of your peers and had several resources available to ask questions, however as an electrical engineer, this was far from the case."

In addition, the participating students cited the following problems:

1. Lack of organization. At Kettering the students are required to organize and manage their own projects. The student's inexperience often showed, and the learning experience was often painful. At Kettering this general problem is amplified by the two student bodies (A-section and B-section) that must work together to build the vehicle, even though they are not on campus at the same time. Said one alum, "Very poorly organized management and communication between sections made for lots of extra work."
2. Lack of funding. Simply put there was never nearly enough money to build the vehicle, as the students really wanted. Spending time on fundraising took time away from working on building the car.

In summing up the problems, one student stated "These are only minor--I think it's an outstanding program, and I wish more students would be involved. I think it benefits the students immensely and the school as well."

When asked how to improve the SAE student program, the responding alumni spent considerable effort to provide thoughtful responses. Most of these suggestions were directed to resolving the previously identified problems. For instance the most common response was to give students credit to work on the competition projects. A couple of the more thoughtful responses were:

- "I believe that the SAE group needs to represent not just the mechanical engineering students on campus but the industrial and electrical engineering students as well. I think it would be great if there were advisors for those departments that tried to encourage participation from non-ME students because from my experience, SAE is very focused on the ME student population on campus."
- "Encourage more involvement from the student population by bringing it up more in classes. Instructors could encourage more participation in SAE by allowing/encouraging students to use SAE projects for class projects. IE's can get involved in ergonomics, bioengineering can get involved in safety, and then of course there's thermo/heat/fluids,

machine design, etc. Get the business students involved with the marketing and budget presentations. Our school is practically built around making the perfect Formula SAE presentation! There should be no reason for us not to win every year."

Conclusions

This paper has briefly described many of the activities conducted by the Kettering student section of the Society of Automotive Engineers. The authors have been involved with these activities for many years, because of their belief in the value of these activities, to the students, to the university, and to the profession. The results of the SAE alumni survey provide considerable support to that belief.

The students that participated in SAE activities believe that there education was enhanced by their participation. Their responses indicate that the university also received benefit because their alumni's perception of the university has been enhanced, and their graduates are more prepared for employment. The alumni's responses also indicate that industry employers are benefiting because they are able to hire more experienced students.

Both participating and non-participating students indicate that the program is valuable, and suggest similar ways in which the SAE programs can be improved. Both groups of alumni indicate that more students would be involved in the program, if they could receive credit for their participation. It would make it much easier to justify the time commitment. Both groups also recommended integration of SAE topics into their courses, and to find additional non-ME oriented projects.

Acknowledgements

Work on this course has been conducted with the help of many faculty, staff and students. The authors would particularly like to express their gratitude to the following individuals: Mr. Ray Rust and Mr. Clint Lee, Engineering Technicians for their contributions.

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