# AC 2007-2879: USING THE SAE COLLEGIATE DESIGN SERIES TO PROVIDE RESEARCH OPPORTUNITIES FOR UNDERGRADUATES

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# Using the SAE Collegiate Design Series to Provide Research Opportunities for Undergraduates

Providing the students with a real world challenge can be used to motivate them to achieve a higher level of learning. However, these experiences can be difficult to design and conduct in a traditional classroom experience. Student design competitions can be used as the basis to provide undergraduate research opportunities for students and faculty. This provides students with the opportunity to participate in real-world research, while, providing faculty with additional applied research opportunities.

This paper provides case studies detailing how Society of Automotive Engineer (SAE) Collegiate Design Series competitions can be used to provide undergraduate engineering research. For example, we have used the competitions as a starting point for advanced studies in alternative fuels and occupant protection. Finally, the results of surveys of alumni who have participated in these research experiences is used to provide an assessment of the benefits of these types of activities.

## Introduction

It can be difficult for faculty to devote time in providing exceptional design and applied experiences to undergraduates while also trying to develop their research. Often faculty members find that these priorities compete for their time. This is particularly difficult for young faculty. Because of this, teaching is often limited to textbook experiences as these faculty spend time working to develop their research. This has led to a gap between what universities are teaching, and what engineers are expected to know in industry.[1] Engineers in industry spend much time working on complex system integration, yet few engineering graduates understand this process.[2] 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."

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. Working on applied research projects can meet these challenges.

The Society of Automotive Engineers (SAE) annually conducts a series of collegiate design competitions where students from Universities throughout the world compete. Many schools integrate these competitions into the capstone design course. Capstone projects are valuable in this regard, but taking these projects one step further to the point of doing applied research projects adds even more value for both students and faculty.

This situation can lead to a "win-win" experience for the students and the faculty involved. The students have the opportunity to participate in real research and can graduate from the university

with a publication record. For the faculty, it is a chance to develop their academic and applied research resumes. This can be particularly valuable in helping new faculty. Further, this research can lead to additional funding opportunities for the faculty member. Finally, this helps faculty to justify the additional time required to develop advanced experiences for their students.

At Kettering University, we have done this for two of the SAE design competitions. Using these competitions as a starting point for additional study, we have been able to include students in relevant research topics, leading to publication and presentation at professional level conferences, both nationally and internationally.

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.

**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 two challenges: SAE Clean Snowmobile, and SAE Formula Design.

These challenges were designed to attract a variety of students with differing interests- from working on environmental concerns to 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're 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.

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.

Finally, by working on particular focus areas, these challenges can be used as a basis to provide undergraduate research opportunities for students. Descriptions of two of these challenges and how they were leveraged for applied research are provided below.

**Using the SAE Clean Snowmobile Challenge for Applied Research**

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 competed against a control snowmobile that was powered by a two-stroke engine; this year, the control snowmobile is powered by a much cleaner four-stroke engine. Further, the competition now allows the use of alternative fuels such as high-blend ethanol as E85 (85% ethanol and 15% gasoline).

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 and emit significantly less exhaust emissions than current production snowmobiles, while maintaining the performance levels expected of a typical snowmobile. Further, the modified snowmobiles are also expected to be cost-effective and comfortable for the operators to drive. Finally, the environmental hazards of snowmobiles have come under scrutiny by environmental protection organizations and the federal government. Currently, parks are operating under a temporary winter use plan which restricts the number of snowmobiles entering the parks per day. All snowmobiles are required to be Best Available Technology (BAT), which are the cleanest and quietest commercially available snowmobiles.[3] Thus, the development of clean snowmobile technology is also an area of interest to manufacturers. Events include emission testing, acceleration, hill climb, cold start testing, noise measurement, fuel economy, durability & range, and both oral and written design presentations as shown in Table 1. A photograph an entry is shown in Figure 1.

Table 1 Clean Snowmobile Challenge events and competition points.[4]

| Event | Rule | Points for Passing Event | Maximum Additional Points for Relative Performance in Event |
|---|---|---|---|
| Engineering Design Paper | 9.4 | N/A | 100 |
| Cost Assessment | 9.5 | N/A | 50 |
| Emissions IC Engines only | 9.6 | 100 | 200 |
| Oral Presentation | 9.7 | N/A | 100 |
| Fuel Economy/Endurance | 9.8 | 100 | 100 |
| Range/Capacity | 9.8.5 | | |
| (for Electric and Zero Emission Snowmobiles only) | 9.8.6 | | |
| Acceleration | 9.10 | 50 | 50 |
| Objective Handling | 9.11 | N/A | 75 |
| Subjective Handling | 9.12 | N/A | 50 |
| Cold Start | 9.13 | 50 | N/A |
| Rider Comfort | 9.16 | N/A | 75 |
| Static Display | 9.15 | N/A | 50 |
| Objective Noise | 9.9.3 | 150 | 0 |
| Subjective Noise | 9.9.4 | 0 | 150 |
| Tech Inspection Bonus – Pass on the 1st Try | | 10 | N/A |
| Tech Inspection Bonus – Pass on the 2nd Try | | 5 | N/A |
| Maximum All Events | | 460 points | 1000 points |

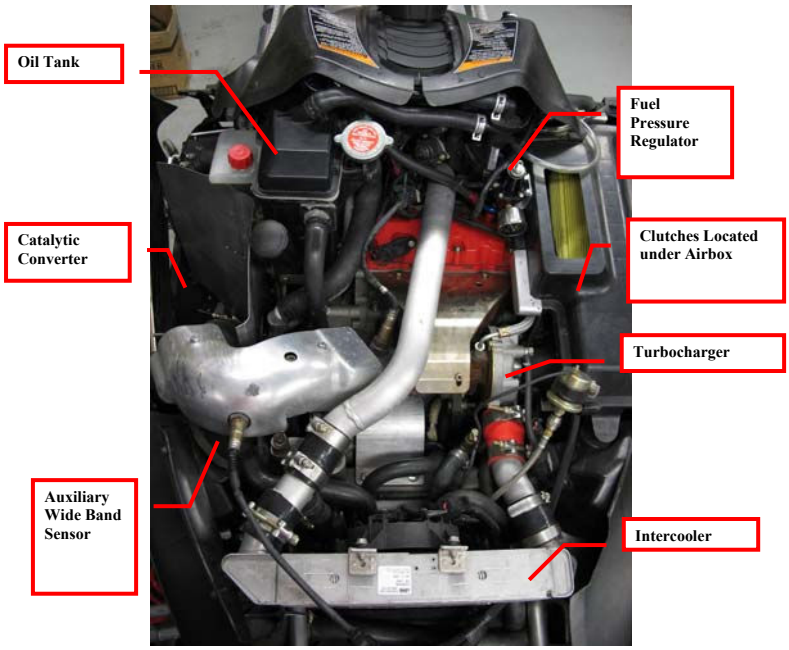


Figure 1. Underhood View of Kettering University's Winning Entry in Action during the 2002 Competition.

By focusing on a particular challenge posed by this competition, it can be used as a basis for further study to provide research opportunities. Kettering University chose to compete using E85 fuel. Since there are no production snowmobiles that utilize E85, this focus area was used as the basis for an applied research project.

The faculty advisor worked with the students to conduct an applied research and development project which focused on the design modifications and potential challenges posed by the use of E85. After developing the snowmobile, it was then tested and the results were compared with those of snowmobiles operating on conventional fuels. Figure 2 compares emissions results of the baseline snowmobile, the final Kettering design, and the 2012 emissions standards (which must be met to receive points for competition).

As is seen, not only did the team significantly reduce emissions as compared with the control snowmobile, but they also significantly reduced the emissions as compared to the new EPA regulations set for enforcement in 2012. The snowmobile design and performance was published in a technical paper which was presented by the faculty advisor and one of the students at a professional society conference.[5] Further, because the use of ethanol as a fuel is important to farmers, this applied research was supported by a grant from the Michigan Corn Growers

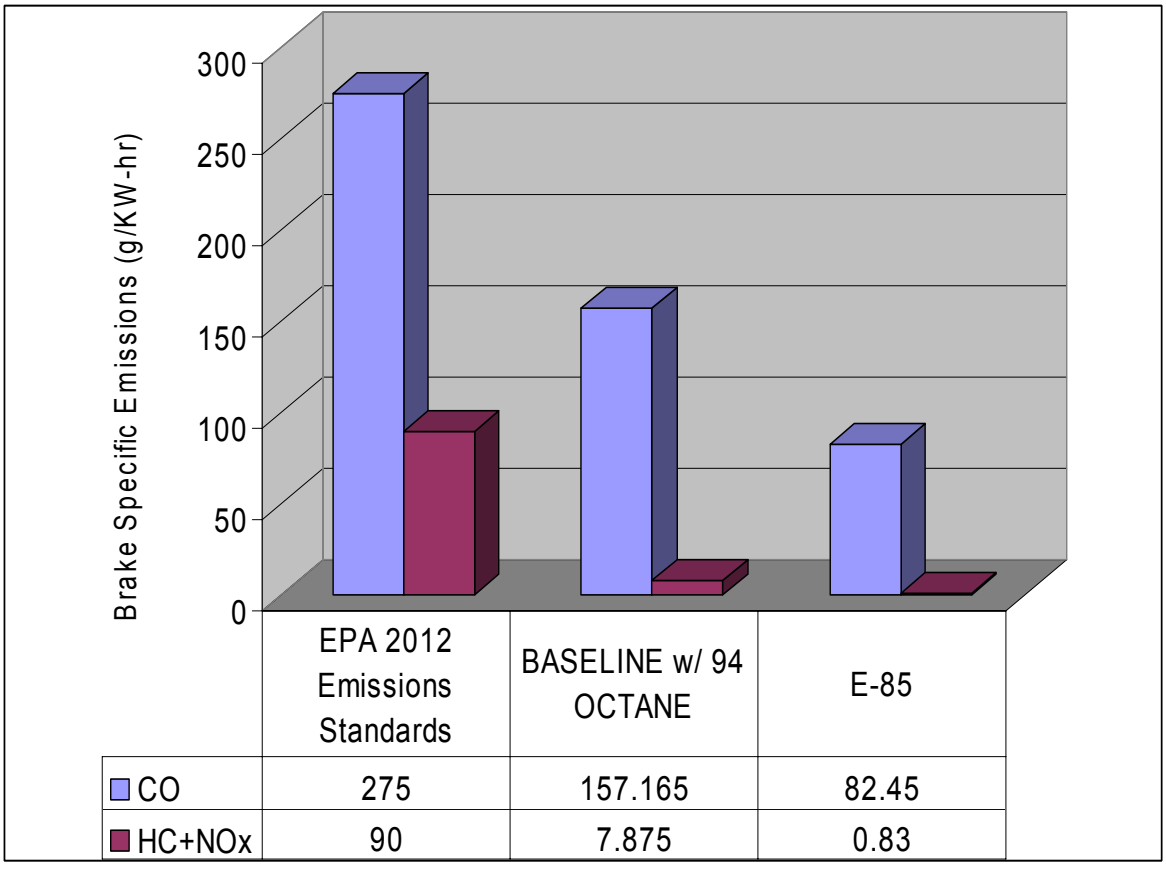


Figure 2. Emissions Comparison between 2012 EPA standard, Baseline Control Snowmonile with Kettering University's E-85 snowmobile.

Association. Further research into the best utilization of E85 is ongoing.

By focusing on the use of E85 fuel to develop a clean snowmobile for the competition, the team was able to leverage this activity in order to conduct relevant applied research. This gave the students experience in developing a research plan, and documenting this work in professional publications and presentations. Additionally, the team was able to accomplish more due to the additional monetary support received for the research project. The faculty member involved received the benefit of having these dedicated students work to conduct this applied research project, while allowing him to provide them with an exceptional undergraduate experience.

**Using the Formula SAE Challenge for Applied Research**

The Formula SAE series is a collegiate competition which challenges students to design, build and compete with open-wheel formula-style race cars. An example of a FSAE car is shown in Figure 3. Since its beginnings in the USA in the 1980's the series has grown to include events in the Michigan, California, England, Australia, Brazil, and Italy. Thousands of students from hundreds of universities around the world participate.


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.

As shown below in Table 2, the vehicles are judged in two different categories: static inspection and engineering design, and high-performance track dynamic events. While mainly conceived as a design activity, the Formula SAE competition has also provided opportunities for research.

Table 2. Events and Competition Point Structure for the Formula SAE Challenge.[6]

| | |
|---|---|
| **Static Events** | |
| Presentation | 75 |
| Engineering Design | 150 |
| Cost Analysis | 100 |
| **Dynamic Events** | |
| Acceleration | 75 |
| Skid-Pad | 50 |
| Autocross | 150 |
| Fuel Economy | 50 |
| Endurance | 350 |
| **Total Points** | **1,000** |

In recent years the Formula SAE rules have stipulated the use of an impact attenuation device to lessen the severity of a frontal impact. In 2006 the rules on the attenuator were modified and specific performance requirements were mandated. The impact attenuator was required to decelerate a 661 lb mass with a velocity of 23 ft/s (7.0 m/s), such that the average deceleration would not exceed 20 g. These criteria were scaled from professional FIA racing regulations, but there was no testing and/or analysis used to justify the values. The Kettering University FSAE team was in a unique position of having the appropriate equipment at their disposal (through their faculty connections) to put these criteria to the test and to provide meaningful feedback on the rules to the FSAE rules committee.

To test the criteria a series of crash tests were conducted using the deceleration sled at the Kettering University Crash Safety Center. The sled, run on pneumatic power, can propel a vehicle interior up to 20 m/s into a decelerator attached to a concrete barrier. The decelerator can be tuned to reflect the type of deceleration that occurs during an impact. A stripped-down Formula SAE chassis was fixed to the test sled and an 50$^{th}$ percentile male Hybrid III Anthropomorphic Test Device (ATD) equipped with accelerometers was used to measure the loads on the driver. See Figure 4.

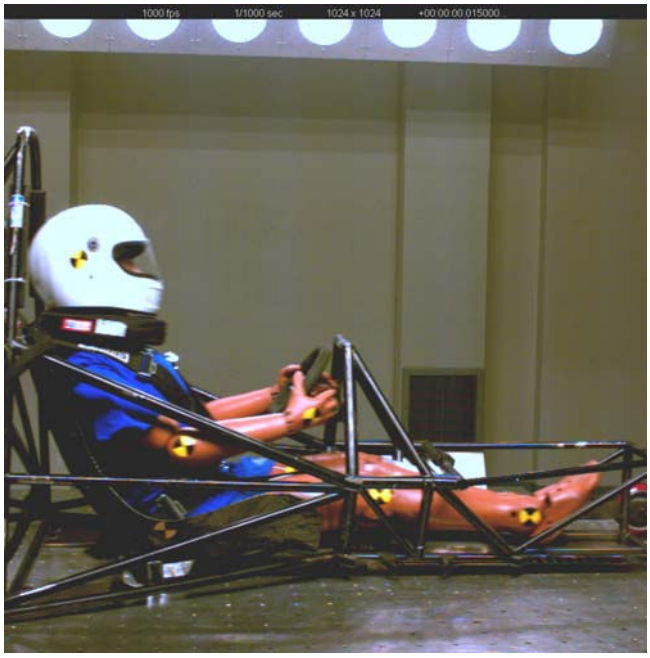


Figure 4. The car frame with test dummy just prior to impact

Tests were performed at the SAE specified conditions and it was found that the criteria were very conservative. There was a very low chance of driver injury. For example, the data in Figure 5 shows that the neck injury criteria are well within the 'safe' region of the Kite diagram. The severity of the crashes was increased to try to find the limits of the 'safe' region, as shown in Figure 6.

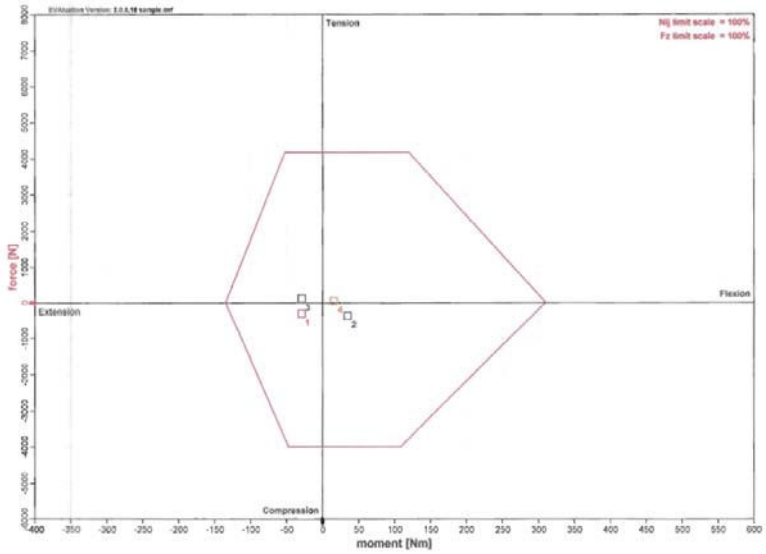


Figure 5. Kite diagram for neck injury criteria, for SAE specified conditions (7.0 m/s, 20-g average deceleration, 35 ms pulse time).

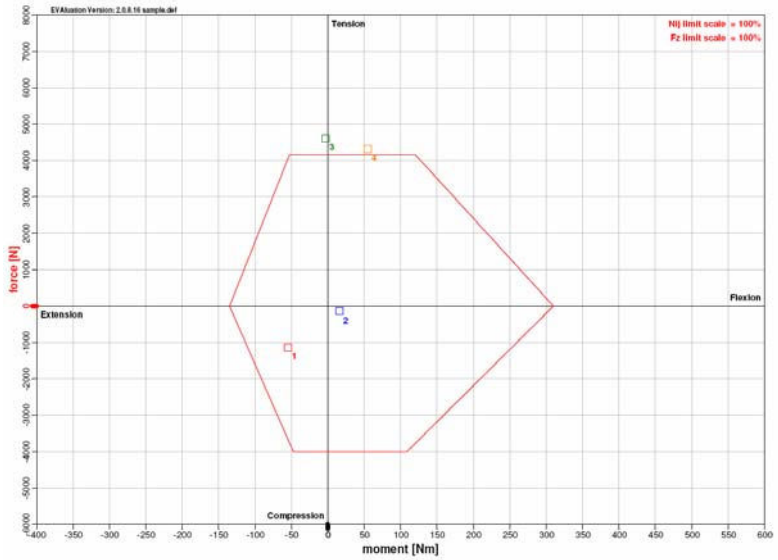


Figure 6 Kite diagram for neck injury criteria, for crash at critical conditions (15.6 m/s, 20-g average deceleration, 80 ms duration).

The results of these tests were presented at the SAE Motorsports Engineering Conference in October 2006.[7] There was considerable discussion among the crash safety experts in attendance about the interpretation of the results, but there was uniform praise for the students for their efforts. There will most likely be changes to the FSAE rules and additional follow up testing.

The students on this project had a truly unique experience. First, because of the equipment they were allowed to use to complete their project and secondly, because they were able to defend their work in front of a group of industry experts. The faculty involved on the project were able to combine their interest in supporting the students, yet were also able to generate a research paper, which is so important in the promotion and tenure process.

**Assessment**

To evaluate the effectiveness of this approach in preparing graduates for careers, 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%).

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 7.

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 7. 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 8). 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. This clearly indicates that these alumni valued the educational experience provided to them.

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 8 Changes in perception due to participation in SAE student activities.

When asked, “What was the best part of being an SAE student member?” One of the students responded as follows: “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).” This is a key ingredient for academic success.

Finally, through their experiences in documenting their research as undergraduates, many of our former students have continued to remain professionally active-publishing and presenting their work. These students have commented that working on research projects as undergraduates under the guidance of their faculty advisors helped to instill them with the confidence to carry on as professionals.

**Conclusions**

This paper has briefly described some of the activities and applied research conducted by the Kettering faculty and students using the competitions of the Society of Automotive Engineers as a basis for further study. The authors have been involved with these activities for many years because of there 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. The alumni’s responses also indicate that industry employers are benefiting because they are able to hire more experienced students.

Faculty, too, benefit from this collaboration. They can devote time to projects that enhance both undergraduate educational opportunities and their own research interests. This research not only leads to additional opportunities to publish and present, but also for additional research funding. This is a rare “win-win.”

It is hoped that this paper will help other faculty to find ways to become involved in these rewarding projects. Young faculty members, in particular, are sometimes dissuaded from participating in these types of educational activities with students as they need to focus on developing their research. By combining these activities with areas of their research interests, these faculty members can spend time advising students and developing their research. Further, the students can provide valuable assistance to the faculty member in conducting the research, while gaining valuable professional experience in preparation for their own careers.

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