Educating New Formula Society of Automotive Engineers (SAE) Members

By:
Michael Abadjiev
Robert Duff
Jarred Measmer
Samuel White
John Williams

Advisor:
Professor Nicholas Bertozzi

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ABSTRACT

The purpose of this project was to improve SAE Club membership growth and development by creating and hosting seminars to educate new members about the basics of cars, engineering, and Formula SAE (FSAE). By hosting these seminars weekly, we aimed to have ample time to introduce a multitude of topics and allow members to gain information from lectures as well as hands-on activities. Each seminar took place for three hours on a Saturday. To gain an understanding how our project was impacting member involvement, we surveyed attendees afterwards with a standardized survey each week. Based upon the survey responses, it was clear that members learned new material and were enthusiastic for the following week's seminars. It was also evident by continued and steady attendance that the seminars had a positive contribution towards helping people get involved with the club.

ACKNOWLEDGEMENTS

We would first like to thank our IQP advisor, Professor Nicholas Bertozzi, who provided excellent support and encouragement throughout the project. We would also like to thank Professor Bertozzi for his generous contribution towards the expenses of this project. We would like to thank the Worcester Polytechnic Institute Formula SAE Team for supporting and promoting our seminars. Additionally, we would like to thank our guest speakers, Professor Kenneth Stafford and Mr. Bill Gendron for sharing their valuable experiences and knowledge.

EXECUTIVE SUMMARY

The purpose of this Interactive Qualifying Project (IQP) was to develop instructional material for the Worcester Polytechnic Institute (WPI) chapter of the Society of Automotive Engineers (SAE). This material was developed to improve new member involvement and increase retention. Every year, students at WPI work all year to build a racecar for an international collegiate design competition held in Michigan. The design and fabrication process is intense, and new students can easily be lost in the rush. To integrate new members faster, the IQP team conducted a series of seminars to both educate new members and pique interest in the team.

Each of these seminars consisted of a presentation followed by an activity, with lunch in between. The presentation covered one aspect of the SAE experience, and was paired with a relevant activity. Seminars were designed by the project team on a weekly basis. The presentation content, as well as the activities for each seminar were completed and tested three days before the seminar. The remaining three days were used to rehearse and refine the delivery of the presentation.

- The first seminar presented an overview of many types of automotive engineering competitions, highlighting the Formula SAE competition specifically. This seminar also included information about the FSAE rules and an activity focused on designing crash safety features for a 1:10 scale model of an FSAE vehicle.

- The second seminar was designed to introduce the fundamentals of internal combustion engines. Additionally, the seminar provided an opportunity to learn about the factors impacting engine performance. The hands-on activities consisted of disassembly and reassembly of two common racing engines, examining camshaft specifications, setting spark plug gaps, and a team-based engine design challenge using computer simulation tools.

- The third seminar was focused on manufacturing and design skills and knowledge. This seminar presented an overview of the different machines in a machine shop as well as a comparison between subtractive manufacturing techniques and additive manufacturing techniques. The activities for this seminar included a SolidWorks assembly challenge and an opportunity for using a drill press and learning how to tap holes for threads.

- The fourth seminar covered a combination of vehicle electronics and the basics of automotive aerodynamics. The seminar included a guest lecturer, Professor Kenneth Stafford, who talked about the evolution of automotive driver aids. The seminar content included an exploration of electronic components in a Formula SAE car as well as an examination of different aero components and aero packages for vehicles. The first activity had several components: diagnosing a no-start condition on a FSAE vehicle using a multimeter, exploring circuit theory with an online simulation, and a tutorial on soldering. The second activity was a team-based competition involving creating an aero package for a 1:10 scale FSAE frame that achieves the most downforce with the least weight. The aero packages designed by the teams were tested in a wind tunnel designed and manufactured by this project group.

- The fifth seminar was focused on the fundamentals of suspension design and vehicle dynamics. The seminar began with a presentation by professional race engineer and driver Bill Gendron. The seminar then moved into the vocabulary and history of suspension design. The activity in this seminar was to design a tube frame for a formula car out of plastic drinking straws and torsion test them. After the activity, there was a short presentation focused on tire technology.

- The final seminar covered driver strategies for racing. This began with an explanation of safety equipment and its applications. The presentation then transitioned into strategies for reading the racetrack and developing good racing lines. We closed with tips for identifying the different modes of traction loss, and how to correct them. The activity portion of the seminar consisted of traveling to the WPI FSAE testing facility at Milara Inc. and allowing each attendee the opportunity to drive. The participants walked the race course to study it before suiting up in protective gear and taking turns driving a Formula SAE racecar in a closed, controlled environment.

Attendance for the seminars ranged from 13 to 26 participants. Feedback was collected after each seminar in order to gain an understanding of what people enjoyed and what they wanted to learn more about. The feedback was helpful for refining the seminar structure and presentation methods. During A-term, there was an approximately 50% increase in participation of new members in WPI's SAE Shop. Additionally, the first B-term meeting of WPI's Society of Automotive Engineers chapter had 20 members in attendance. Both of these point to the seminars having a positive impact on engaging new members and integrating them into the team.

In summary, the goal of this IQP was to develop educational materials relating to automotive engineering, to be used by WPI's Society of Automotive Engineers to improve new member retention and education. This material was presented in the form of weekend seminars consisting of a presentation followed by an activity to provide hands-on experience. We found that the seminars were successful in both retaining a greater number of new members, as well as providing new students with a foundation that made them more comfortable asking questions and getting involved with the club.

Based on our project experience and feedback from those that attended, several recommendations for use of the course materials follow:

- Keep all technical presentations under 30 minutes
- Provide guest speakers with focused talking points
- Divide course material into one-hour seminars to be taught weekly at WPI's SAE chapter meetings

AUTHORSHIP

Section	Michael Abadjiev	Samuel White	John Williams	Robert Duff	Jarred Measmer
Acknowledgments	Editor	Author	Editor	Editor	Editor
Executive Summary	Author/Editor	Author	Editor	Author/Editor	Editor
Preface	Author/Editor	Author/Editor	Author	Author/Editor	Author/Editor
Introduction	Editor	Author/Editor	Author	Author	Author/Editor
Background	Author/Editor	Author/Editor	Author	Author	Author/Editor
Methodology	Editor	Author/Editor	Editor	Author/Editor	Author/Editor
Findings	Author/Editor	Editor	Author/Editor	Author/Editor	Author/Editor
Conclusion	Author/Editor	Editor	Editor	Editor	Editor
Recommendations	Author/Editor	Author	Author	Editor	Editor
Appendix D	Author/Editor	Author	Author	Author/Editor	Editor
Appendix E	Author/Editor	Editor	Editor	Author/Editor	Author/Editor

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

Formula SAE is a collegiate level design competition challenging students to design an on-road formula style vehicle for potential sale to weekend autocross enthusiasts. The competition requires students to complete every aspect of the engineering design process, from the business model and cost of production to the design and performance of the vehicle.

The formula team at WPI is split into two groups of students. One group is part of the annual Major Qualifying Project (MQP), and is responsible for the design and validation of the vehicle to a strict set of rules for the FSAE competition. The rest of the undergraduate students involved assist the MQP team to manufacture and assemble the vehicle. This model allows a professor to oversee and evaluate the design of the vehicle's systems while providing critical hands on experience for the SAE club members.

SAE club members are also welcome to design and build their own systems for the car, either alongside, or in addition to the competition requirements. Previous projects from club members have included a custom Formula 1 style steering wheel and a full carbon fiber body. Club members also undertake independent efforts to redesign and upgrade previous SAE cars. In past years this has included converting a previous car from internal combustion to electric drive. There is currently a team developing an autonomous control system for the same electric vehicle.

WPI's SAE club has a consistently positive impact on WPI undergraduate students. This includes providing hands-on engineering experience and attracting recruiters to visit WPI from prominent companies, including Ford Motor Company, Uber Technologies, and Space Exploration Technologies Corp. (SpaceX). Some students have even been offered full-time positions as a result of their Formula SAE involvements. SAE consistently receives interest from prospective students, usually in the range of 60-70 students per year, based on previous headcounts at initial interest meetings. This year, there were 68 students in attendance at the first chapter meeting of SAE. SAE is an important component to the WPI community and it serves a critical role in engaging students in design.

INTRODUCTION

Worcester Polytechnic Institute’s chapter of the Society of Automotive Engineers (SAE) has trouble every year retaining new members. Part of the problem is a lack of experience in automotive engineering, and another issue is that club members are unable to teach new students while also working on the SAE car. Our strategy to solve this problem for both the current year of incoming students and years after involved designing a compact, hands-on, educational curriculum that is aimed at providing a breadth of introductory material and basic skills. This material was taught as it was developed to integrate feedback and reflection in order to maximize success.

Previous efforts have focused on both social activities and teaching SOLIDWORKS, an industry standard computer aided design (CAD) software. Social activities have been successful at building interpersonal relationships between team members, but were not effective at retaining members in the long run. SOLIDWORKS tutorial sessions are popular with SAE members, however, the focused nature of the sessions results in a failure to integrate the content into SAE. Prior to this project, there was a distinct lack of new member engagement.

The ultimate goal of this project was to improve new member involvement by educating students on the basics of SAE related material. This had a positive impact on the involved students by providing them with useful knowledge, skills, and team experience for their future careers as engineers.

BACKGROUND

Problem

WPI's SAE Team has difficulty retaining new members every academic year. A large factor in this struggle is that incoming freshman do not have the engineering skills or experience to do many tasks without significant coaching, let alone the exposure to know what aspect of automotive design they would be interested in working on. WPI's SAE team does not have the manpower to be able to train all of the new members every year, especially when all the active members are working hard to prepare for competition. This results in many new students not getting attention from active members, not learning about SAE, and not getting experience in automotive design and engineering. New student members therefore stop participating in WPI SAE activities because the club fails to engage them and they wind up dropping out of SAE. Club records for the 2017-2018 school year show a drop from 69 new members at the first chapter meeting in A term 2017, to 7 actively involved members at the end of B term 2017. This is a serious problem for the club, and detracts from the freshman experience for some at WPI. New students can end up quite disappointed that the existing team is too busy with the design process to get them up to speed.

Past Work and Research

Prior to our project, another IQP group studied club growth and development at WPI. In doing this project, the group surveyed students around campus about campus club involvement. It was found that 18% of students left or refused to join clubs because of poor leadership, while 8% left or didn't join due to a lack of knowledge in the subject area of the club. These are two issues which have consistently been a problem year to year in the WPI SAE club. The previous researchers also stated that: "Current observed problems include the lack of a new member education program, officer transition program, and seminars for showcasing different design and manufacturing techniques." (Pickering, 2015)

The past IQP also surveyed several other schools about new member involvement in their Formula SAE programs. The Massachusetts Institute of Technology (MIT) typically plans Saturday seminars to educate new members and also has a small credit class recognized by the school as a design review for new members. Rennselaer Polytechnic Institute (RPI) does not have an organized seminar system, but they have a larger team which can afford to take time to train new members. The most common system between both schools however was dividing the team into the different subsystems on the car. The purpose of this was to expose new members to a broad number of topics, which resulted in them finding what they are most interested in and getting them working on that particular system.

Based on this particular source it was clear that a weekend new member education program was the best solution for our particular situation. A common theme with education programs of the other schools interviewed was dividing the team into subteams based on subsystem in order to allow members to work on what they are interested in, which was proven to help with retention. We addressed both of these by having weekend seminars which covered each of the main subsystems of the car. This allowed our new members to get an introduction to a broad amount of topics, and really find their interest.

Solution

As active members and leaders of WPI's chapter of SAE who are passionate about the success of WPI's SAE Team, we proposed this Interactive Qualifying Project to begin the solution of this deficiency of automotive education and engineering exposure. We envisioned a comprehensive yet concise hands-on curriculum that exposes new members to all aspects of automotive engineering and design as well as equipping new members with relevant skills that allow them to have confidence and be successful in jumping in on whatever area of engineering they are excited about. This project was completed throughout A and B-term of 2018, with hands-on educational sessions for new members held on six Saturdays during A term, for 2-4 hours each session. The portion of the project performed in B term consisted of a reflective analysis of the seminars from A term, writing a paper, and setting up and revising material for future club leaders to be able to continue to lead similar seminars in future years. Feedback surveys taken at the end of each seminar were analyzed in order to optimize the seminars to promote member involvement. This solution not only improves the new member retention rate and participation, but it also gives freshmen an early opportunity to learn more about what kind of engineering they want to study at WPI. Discovering this through WPI's chapter of SAE enriches their education at WPI by allowing them to focus their studies right from the start of their education and give them a fulfilling experience where they can apply their passion on a team with other aspiring engineers.

Objectives & Evaluation Metrics

This IQP had three primary objectives. The first was to retain at least 50% of new members, meaning that the last seminar should have at least 50% of the amount of students present at the first seminar. Additionally, we wanted to give our incoming students both academic knowledge that is useful for the team, as well as hands-on experience that so many freshman lack. This experience will help students to decide their direction of study. Many incoming college freshmen do not know what they want to major in, much less what they want to do with the rest of their lives. We gave these students a window into the world of engineering project management, which they can use to decide if they want to continue with their chosen path. Finally, this IQP was aimed at creating a system for passing on information to future teams. The team needs to establish a tradition of training new members and building a knowledge base, rather than starting from scratch every year.

METHODOLOGY

We planned to meet our goals by designing, creating, and implementing a series of six educational seminars held on Saturdays throughout A-term. These educational seminars consist of lecture-based learning and presentations, as well as hands-on activities. All of these seminars were presented in such a way that new members to the team learned and also enjoyed themselves. In addition, they were given a chance to pinpoint their interests in the different areas of engineering covered. Following the conclusion of the day, we asked for feedback on the day's events, and modified lecture and activity material for both past and upcoming seminars to be more useful for future use. We used a standardized survey in order to see where we were improving vs. what we needed to work on. This survey can be found in Appendix A; the numerical results of this survey are in Appendix B, and the tabulated written responses in Appendix C.

Content and demonstrations for each seminar were developed in the week prior, previewed by the advisor, and reflected and revised on after the seminar was conducted. This content is available in the attached folder called, "SAE IQP Export Folder." In Appendix E, there is a high-level summary of each seminar that details how the seminar was conducted.

Our process for creating the seminars began by brainstorming the topics that are both relevant to the Formula SAE racing competition and to the automotive industry. Table 1 shows the seminar topics showing the initial plan and the actual plan. The seminar topics were reordered to present the material in a way that gradually builds up, with a focus on keeping the seminars engaging, educational and fun.

Table 1: Seminar Topics (Planned vs Real)

Seminar	Preliminary Seminar Topics	Final Seminar Topics
I	Vehicle Dynamics	Introduction to SAE
II	Engine Basics	Engines
III	Electrical Systems	Manufacturing
IV	Manufacturing	ECE + Aero
V	Driver Strategies	Vehicle Dynamics
VI	SAE Competition Basics	Driver Strategies

The seminars were grouped into six seminars because we decided that two weeks would be enough time to promote the first seminar, and then following that seminar we would keep the seminars to a regular schedule that people could plan around. Maximizing the number of seminars in one term allows the content to be spread out. Even so, we still had to consider whether the content we selected for a given seminar would be too much or too little. We also wanted to have the seminars build upon each other so that the perceived complexity of the content remains relatively constant.

Each seminar was created, start to end, in ten days. For a seminar being held on a Saturday, the Thursday before the team would identify the learning objectives and begin to brainstorm hands-on activities. Friday and Saturday would be focused on both the previous seminar and continuing to brainstorm interactive team activities. Sunday the team would outline the content to be covered and finalize the activities for the seminar. Monday the team would fill the outline of content with the information to be presented. Tuesday any remaining information would be added to the content outline, and a presentation would be created from the content. Wednesday the presentation would be finished and the activity would be tested. Thursday the team would meet to add slide notes, rehearse, and make modifications to the organization. Friday the team would practice the presentation again and make any last minute changes. Saturday, before the seminar, the team would prepare the presentation and lay out the materials for the activities. If necessary, the team would run through the presentation once more to make sure timing and the depth of technical explanations was appropriate.

There were several sources of ideas for the hands on activities, ranging from textbooks to high school competitions to shop class activities. Each hands-on activity was thematically linked to the content of the presentation, and was done after the relevant content was delivered. The idea behind this was to reinforce the content from the presentation with visual and physical learning aids. This makes the seminar more engaging, as it gives the students in depth of knowledge right at the beginning of their experience.

FINDINGS

In order to gauge the effectiveness of our project, we gave a standardized survey after every seminar to collect data on the material covered. The survey asked attendees to evaluate the quality, and difficulty of both the presentation material and the accompanying activity, as well as some questions about what they liked, disliked, or would like to see improved upon. By using the same questions each week, we were able to see how the perception of our seminars changed and were able to adapt them to make them more educational and enjoyable. An example survey can be found in Appendix A. The first four questions were numerically based, as described below:

1. How would you rate the quality of the presentation?
    a. Scale of 1-5, where 1 is 'terrible' and 5 is 'excellent'
2. How would you rate the complexity of the material covered for your current skill/knowledge levels?
    . Scale of 1-5, where 1 is 'too elementary/basic' and 5 is 'too complex'
3. How would you rate the quality of the hands-on activity?
    . Scale of 1-5, where 1 is 'boring' and 5 is 'engaging and interesting'
4. How would you rate the difficulty of the hands-on activity?
    . Scale of 1-5, where 1 is 'too easy/elementary' and 5 is 'too difficult'

Table 2 below shows the averaged responses for each question and each seminar. From the average values for each question it is clear that, in general, the quality of the seminars was high, and that the difficulty of both the material and the activity was relatively low. High quality material and activities were obviously desirable, and the results showed that our method for creating and planning the seminars worked well. Additionally, we believe that a lower level of difficulty is desirable, as it makes it easier for newer, less experienced members to get involved, and getting these new members involved was the primary objective of this project.

Table 2: Numerical Question Responses

	Seminar 1	**Seminar 2**	**Seminar 3**	**Seminar 4**	**Seminar 5**	**Seminar 6**	**Average**
Question 1	4.34	4.6	4.73	4.7	4.31	4.44	4.52
Question 2	2.65	3.06	3.26	2.78	3.08	2.77	2.93
Question 3	4.52	4.46	4.4	4.69	4.75	4.88	4.62
Question 4	2.69	2.86	3.06	2.77	3	3.11	2.92

Figures 1-4 show trend lines for the four survey questions. The lines indicate that the quality and difficulty of the presentation remained mostly constant, while both the quality and the difficulty of the activity increased as the seminars progressed. We believe the reason for the greater increase in activity quality over presentation quality stems mostly from our experience as presenters. We have all presented to a class before, and have developed skills for presenting material we understand to another group of people. On the other hand, developing, presenting, and running an activity were all foreign to us, and it took some time to understand how to best engage attendees. Factors such as group size and activity relevance seemed to be the most important.

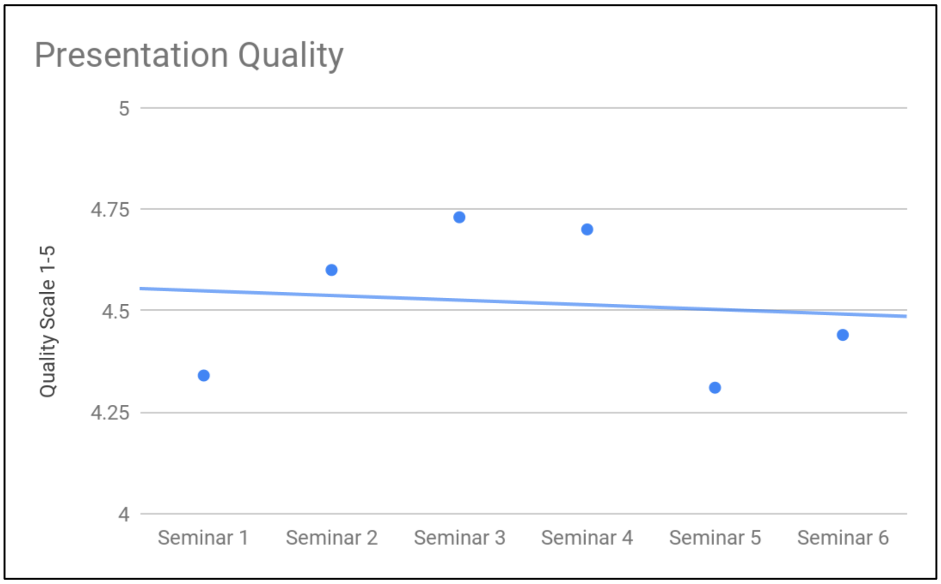

Figure 1: Presentation Quality

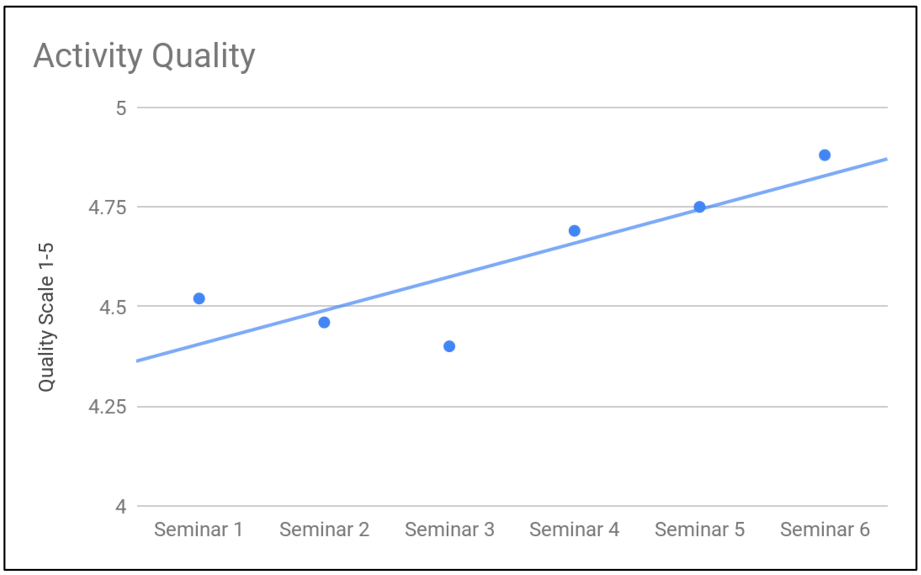

Figure 2: Presentation Quality

For the difficulty of the presentations and activities, the trends shows a more or less constant difficulty of material, and an increasing difficulty of the activity. We believe the difficulty of the presentations was mostly related to the specific material covered. For instance, topics like vehicle dynamics were obviously more difficult than the introduction to SAE. The results show that the material difficulty increased until the third seminar, and then decreased to the last seminar. This is desirable because starting with an easier seminar encourages attendees to keep coming, while an increasing difficulty with the progression keeps them engaged and interested in learning more. An easy, more relaxed final seminar allowed attendees to have fun with the club but still be interested in becoming more involved with Formula SAE.

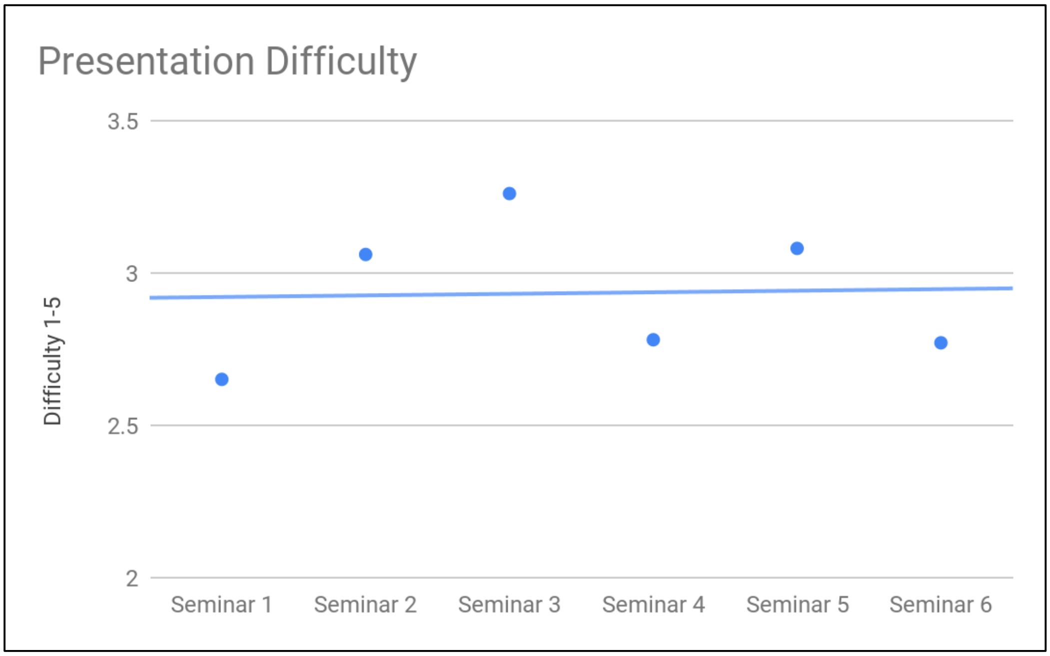

Figure 3: Presentation Difficulty

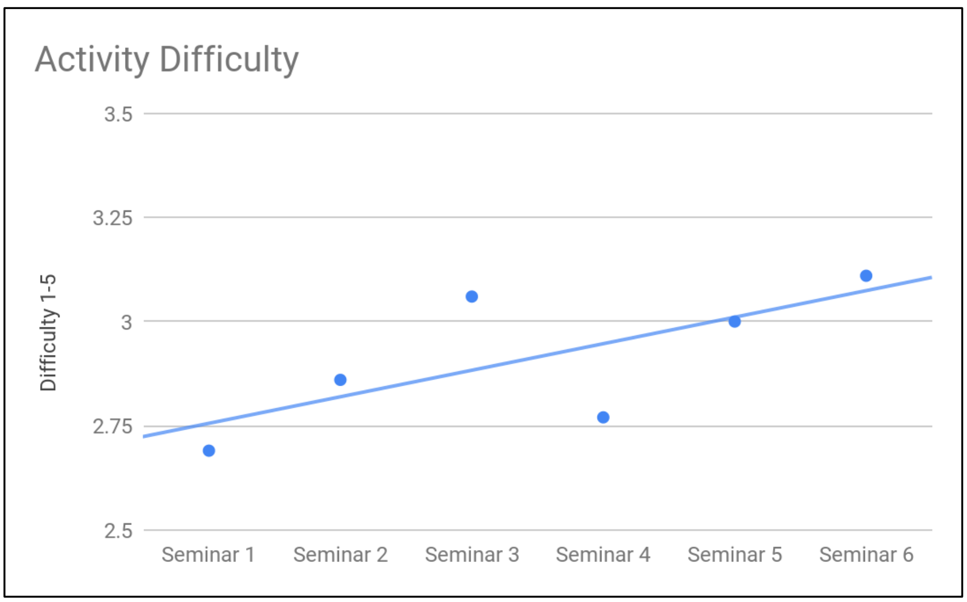

Figure 4: Activity Difficulty

In addition to the numerical questions, we also asked attendees to report on what aspects of the presentations they liked, what they would like to learn more about, and any other feedback they had. The responses to these questions can be seen in Appendix C. This data was analyzed using word clouds generated based on the frequency of the appearance of words. Generally, across all 6 seminars, the most popular parts were the activities and the two guest speakers that we had. There were much fewer negative responses here, most of which related to the organization of the presentation, and decreased in the later seminars. When asked what topics they would like to hear more about, students mostly mentioned topics that were planned to be covered in future seminars. This was an encouraging response, as it meant we were able to meet people's requests at each seminar, and the variety of requested topics decreased over time. The final question asked for any other feedback that attendees had, and mostly contained requests for next week's food or other similar responses. In addition to our survey, we noticed a general average of around 15 people at club events and meetings into B term of 2018. This is higher than the typical 5-8 for the club, but of course cannot directly be traced to this IQP.

CONCLUSION

Our project's goal was to address an important issue in WPI's chapter of the Society of Automotive Engineers: new member retention. SAE struggles each year to engage new students and retain membership after the first few meetings of the year. We helped the club make a significant stride towards new member education, involvement, and inclusion. Future challenges include being able to keep the new members interested. We are pleased with the success achieved with this project, especially as a proof of concept for seminars run by the SAE club. Each seminar was made up of a lecture period, followed by lunch, and a hands-on activity. They covered information from the topic of automotive engineering, ranging from an introduction to the SAE competition, to an overview of vehicle dynamics, and how to approach suspension design. The activities offered attendees a fun way to apply the material covered in lecture to a hands-on problem to solve. Students were encouraged to work in groups facilitating the formation of friendships and camaraderie within the SAE team. After each seminar, attendees were surveyed to determine which aspects of the presentation and activity they enjoyed, and which could be improved upon. The documentation of this survey data in Appendix C will allow for the club to continue to cater content and events towards topics which are most relevant and important for new members to be successful, with only slight changes to the difficulty of presentations and activities as other topics remained constant throughout the course of the seminars.

RECOMMENDATIONS

There are a few specific improvements that could be made to make these seminars better. The organization of the seminars could be improved upon and standardized. Through observation and feedback, the seminar structure that was most successful was to break up the technical content with interactive activities rooted in an engineering problem. We found 30 minutes was the upper-limit of an individual technical presentation. To this effect, guest speakers should also be limited to that same time frame and have a focused discussion planned in advance. Technical content should be split into smaller sections with relevant activities that apply the material. The last organizational recommendation would be to make sure that questions from the audience remain focused on the material.

Another potential point of improvement could be the timing and distribution of the seminars. Our seminars occurred for 3-4 hours every Saturday, which seemed to be a time when most people were free, but did not necessarily want to spend all their time at yet another lecture. For this reason, we would recommend dividing each seminar's content be such that it be presented in smaller presentations lasting about an hour. Seminars can then be run at the weekly chapter meetings, having the added benefit of attracting attendees to the meetings. It would also give the meetings more of a purpose, as opposed to just updating everyone on the past week's events.

From the responses to survey questions, we were able to gather some information on which topics attendees would have liked to see more of, and which they cared less about. For the most part, the results indicated that the future interests of students after a seminar coincided with the planned following seminars. Some topics that were consistently requested, but were not accounted for in our schedule were:

- More advanced topics in SolidWorks, such as simulation and finite element analysis
- More about aerodynamics
- Engine development
- Manufacturing.

With the adoption of shorter seminars, run during chapter meetings, these topics could be more easily addressed specifically, and in detail, as opposed to the brief overview that we gave in our seminars. For instance, the club could run an evening event where a club leader walks members through the steps to design a simple push bar for the car, explaining the fundamentals of SolidWorks Weldments, a crucial element of the SAE design. After the short presentation, attendees can then use what they have learned to develop their own improved design, while a few leaders circulate and offer help and advice where needed.

REFERENCES

Lunati (2008). *Understanding Camshaft Specifications*. Retrieved from http://www.lunatipower.com/Tech/Cams/CamSpecTerms.aspx

Milliken, D. L. (2003). *Race car vehicle dynamics: Problems, answers and experiments*. Warrendale, PA: SAE International.

Pickering, A., Franzini, G., & Sears, Z. *SAE Club Growth and Development* (Rep.).

APPENDIX A: Feedback Survey

9/8/2018 SAE Cars and Coffee Feedback

SAE Cars and Coffee Feedback

1. **How would you rate the quality of the presentation?**
   Mark only one oval.

	1	2	3	4	5	
Terrible	◯	◯	◯	◯	◯	Excellent

2. **How would you rate the complexity of the material covered for your current skill/knowledge levels?**
   Mark only one oval.

	1	2	3	4	5	
Too elementary/basic	◯	◯	◯	◯	◯	Too Complex

3. **How would you rate the quality of the hands-on activity?**
   Mark only one oval.

	1	2	3	4	5	
Boring	◯	◯	◯	◯	◯	Engaging and Interesting

4. **How would you rate the difficulty of the hands-on activity?**
   Mark only one oval.

	1	2	3	4	5	
Too easy/elementary	◯	◯	◯	◯	◯	Too Difficult

5. **Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)**

https://docs.google.com/forms/d/1NVLbRRJBDPoWLySPvxmv2Tt07lALIlzyq0zpbmHWcs8/edit 1/2

6. **Topics you would like to learn more about?**

7. **Any other feedback?**

Powered by
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APPENDIX B: Feedback Survey Numerical Results

	Seminar 1	Seminar 2	Seminar 3	Seminar 4	Seminar 5	Seminar 6
Question 1	4.34	4.6	4.73	4.7	4.31	4.44
Question 2	2.65	3.06	3.26	2.78	3.08	2.77
Question 3	4.52	4.46	4.4	4.69	4.75	4.88
Question 4	2.69	2.86	3.06	2.77	3	3.11

APPENDIX C: Feedback Survey Written Results

Table 3: Seminar I Feedback

Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)	**Topics you would like to learn more about?**	**Any other feedback?**
I really like the presentation. It is really detailed and easy to understand.	Aeros and all these details about the car designs	
I liked building my own car to see what I think will/will not work and how it actually works.	I would like to learn more about how suspension systems work.	
Although I don't have much of a background of automotive terms, the presentation was descriptive enough so I could understand. Very interactive and fun.	Car Parts and features (in general)	
I liked being able to immediately apply what we talked about in lecture as well as getting to work with others!	fabrication methods! Also, just more about cars and how we can integrate electronics and robotics	:)
Did not see everything, egg thing was fun though, maybe better pizza?	Engines, overall car design	
The design of the activity made everyone in the group think about all the parts of a car and how secure everything should be in a stable design.	engine design and control	
I had a lot of fun with the activity but missed the presentation. It looks like the presentation went over basic physics equations that I already knew from high school	how frames are designed (where do rods go, how do you make it strong?)	enjoyable activity overall
I don't feel like writing stuff, but I really liked the meeting	Engines	
It felt like it was okay in content of what was presented but not very efficient for the time given	not sure rn	Vegan food pls
I enjoyed watching the videos of the car during competition. I enjoyed working with other people in making a car that worked well.	I would like to learn more about the skills required to build actual cars for competitions.	
It's simple & nice but still informative	more technical stuff about car parts: engine/tire/steering	Post a work schedule at the shop
I liked how the presentation didn't assume any prior knowledge. I didn't like the time of the meeting, too early.	Being an Aero major, I'd like to know more about the body design and how you decide on each component of the car	
Liked the presentation because it was short and informative. The activity was great as not only another icebreaker but also a good teambuilder.	Aero, CFD	Great Presentation & activity
I liked learning about how the competition worked and what the ~~ parameters were	How to contribute more	Team volvo
Good intro to the basics of SAE. Good to start off basic & get more detailed as the seminars go.	Engine/ecu tuning	
I liked the fun activity	Machining/manufacturing of parts	y'all did good
I liked hearing the rules and what is included in the judging	I want to learn about the suspension system and engine tuning	When are good times to come and help?
Presentation very good, little long on the rules since we had the handout. Activity was fun, would be nice to get to do testing/redesign	practical design info for frame/ suspension	Event could connect more to shop work and competition, lead into other club involvement instead of standalone events.
I liked the intro to FSAE and how you explained what it is, rules, etc. The activity was fun too.Liked group aspect of activity	Suspension, design programs	make presentations shorter in future

Fun to design things that are not tied to a project. More materials or some means of distribution would be nice	Impact Simulation	
good introductory info	suspension and chassis design	
I'm on the team so I already knew everything. It was fine for beginners	Suspension	
I liked the lack of rules so we could really expand our crazy designs	Engines	

Table 4: Seminar II Feedback

Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)	**Topics you would like to learn more about?**	**Any other feedback?**
the presentation went well with explaining the engine components and expanding on some info on types of fuel		
I liked the second half of the presentation after the activities, but I found the first part a tad dry. I liked learning about cams.	Optimizing performance through supercharging as well as efficiency	It was a tad long
I really enjoyed working with enginees. I feel like I learned so much about how they work. I am a complete noob with cars so the design game went over my head		
Difficult to understand, but I missed half of the presentation and don't have any experience	More about how to build cars	
I would have liked to see the material referenced be relevant to SAE, but the spread of material covered and its depth were good	superchargers, fuels, displacement, optimization	Thanks a lot this was an enjoyable way to spend the morning
Dissapointed by lack of coffee	Drivetrains	
Liked disassembly and in-depth look at engines	manufacturing , machining	Good job
I liked how it included both basic and advanced information. Spark plug gap too elementary	Aerodynamics	
Liked hands on activities, they were engaging and relevant	Drivetrain, Suspension, Aerodynamics	Nice Job
informative	Suspension	it was fun
Enjoyed hands-on activity, also building engine in simulation	I think you guys covered everything	
The simulation at the end was a nice application of the information presented	Suspension types and efficiency	
I liked the simplified explanations of the concepts presented and the hands-on was a good way to see what was presented.	Aero CFD	Interesting & Engaging
The presentation wasn't as in depth as I wanted, but hands-on activity was good	Calculations / Testing	
The presentation was well done and perfect on length. The hands-on activity was amazing, much better than last week. Probably could be more relevant to FSAE	Frame , Suspension , Aero	Great Job

Table 5: Seminar III Feedback

Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)	**Topics you would like to learn more about?**	**Any other feedback?**
liked making cad assembly, milling	laser cutting	great job

Knew how to do second activity, but it would have been useful otherwise	laser cutting, Metal 3d printing	very engaging, taught me stuff I didn't know
Could have been more in depth in the manufacturing of the car specifically	How you design the car	
	welding, soldering	
Liked the solidworks assembly, thought the machining activity was dry	solidworks part design	
Activities were fun, but too elementary		
waiting during machining activity was boring		
Liked using tools in activity	tools	
liked solidworks, assembling	solidworks car	
ask for questions more, explain pictures more, mingle more	frame / suspension , wiring	remember to keep it interactive
	aero	good
I liked the variety of material covered and depth for each topic. Drill/tap activity took too long, more stations		
activity was fun, presentation was engaging, good food	suspension	
Liked the activities, 3hr is too long tho	FEA	
Enjoyed hands on activity, questions	suspension / aero	

Table 6: Seminar IV Feedback

Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)	**Topics you would like to learn more about?**	**Any other feedback?**
Overall, very interesting. The professor's presentation was the hook that got us engaged. very interesting hands on sessions. could be more difficult but probably good given the range of experience.		
Aero is cool	suspension	
I liked bringing stafford in. interesting	suspension tuning	electronics presentation could have been better
Enjoyed aero activity		
really liked aero activity	more about engine parts	great presentation and activity
first activity was boring, second one was so much fun	vehicle dynamics, design process	great job
	Solidworks, gears, designing gears in solidworks	not pizza
enjoyed aero activity	frame design, force analysis	excellent presentation
Great job, entertaining		
good mix of theoretical and hands on		
the aero activity was educational, helped me learn about downforce	more aero stuff	
Guest speaker was great, so was aero activity		
Really liked guest speaker, and aero presentations and activities. electronics could have been better.	suspension	more guest speakers

Should have had stafford at the end since he wasn't related to sae. would have liked more directly related to sae	design process	

Table 7: Seminar V Feedback

Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)	Topics you would like to learn more about?	Any other feedback?
Presentation went long, activity too short, great guest speaker	more technical aspects of things we already learned. maybe hear from mqp members	still too early for me
Great guest speaker	Car setup	great job
presentation was too long, enjoyed guest speaker and learning about suspension types		
loved having the guest speaker, the activity was fun	auto materials	
liked involvement of students	engines	
lots of new terms and information		
different applications , drifting	suspension, strategy	
activity was fun and the guest speaker was great		
I liked the variety of information covered but not spending much time on any one topic made it harder to understand everything		
there were a lot of terms and systems that I didn't understand		
I did not like the guest speaker as I did not learn anything. I did enjoy the hands on activity	Solidworks	
Enjoyed how the activity was relevant to formula sae	suspension	
learning about suspension	turbos, superchargers	

Table 8: Seminar VI Feedback

Please give a short description of what you liked/disliked about the presentation and/or activity. (Be honest!)	Topics you would like to learn more about?	Any other feedback?
Excellent insight into proper driving and autocross techniques	car control , maintenance	
The info about how to drive on the racecourse and the "activity" were both fun and interesting		
Could have given examples of good driving vs bad driving		
i liked everything, driving was great and the seminar before hand was also interesting		
Driving	Building the new car	
presentation could have been more in depth, more seat time	more in depth	run both cars at the same time
hitting cones was my favorite part	terminology	
i liked racecar		good job
a more basic intro to the presentation would have been nice		

APPENDIX D: How to Use Our Materials

This appendix section will provide a summary of how any future groups looking to run similar seminars can use the material we generated. The first step is to locate the associated folder containing the material for all six seminars; this is located in the export folder located in the SAE club Google Docs workspace. Within the materials folder, there is a folder for each of the six seminars, each of which contain at least a presentation and a seminar plan document. For some seminars additional material may be included, such as the rules handout used in seminar I. The seminar plan document details the materials necessary to run the activity(s) in the seminar, as well as a rough time layout, and some recommendations about running each seminar. The presentations contain speaker notes on the slides with more detail about what should be covered in that slide.

This folder is useful even for those wishing to use a different structure of the seminars, like dividing them into shorter, one hour events at chapter meetings. The presentations are all structured in such a way that there are sections that can be presented independently, meaning that they can be shortened to be presented during two or three consecutive chapter meetings. Additionally, most of the activities are short enough to be done during a standard SAE chapter meeting. Note that this report and all the materials mentioned above are available in the WPI Electronics Projects Collection.

APPENDIX E: Seminar Summaries

Seminar I: SAE Competition Basics

Our first seminar covered topics related to the structure of Formula SAE competition. The learning objectives for this seminar included basic knowledge about FSAE relative to other automotive competitions, knowledge about FSAE competition events, emphasize the importance of safety, begin to bond teams and members, and introduce the core FSAE rules and design considerations. The structure of the seminar is shown in table 9 below.

Table 9: Seminar I Structure

Content	**Duration**	**Time Start**	**Time End**
Informal discussion and coffee while people show up	10 minutes	11:00 am	11:10 am
Icebreaker	15 minutes	11:10 am	11:25 am
Presentation	35 minutes	11:25 am	12:00 pm
Handout	5 minutes	11:40 am	11:45 am
Activity: build, lunch	60 minutes	12:00 pm	1:00 pm
Activity: design presentation & review	20 minutes	1:00 pm	1:20 pm
Test vehicles	40 minutes	1:20 pm	2:00 pm

The informal discussion and coffee at the beginning of the seminar allowed us to socialize with the attendees and get to personally know them. It also gave enough of a buffer that people that showed up late didn't miss any educational content. After gathering everyone's attention and introducing the seminar series, we started an ice breaker where we gave our name, academic year, major of study, home state, dream vehicle, and any other interesting personal fact. This short activity allowed those in attendance to learn the names of others and find relations on various interests or other connections.

The presentation for the first seminar, found in exports folder, introduced SAE as a regulatory body that develops standards for several transportation industries and also develops the rules for all SAE collegiate competitions. Next we emphasized the core purpose of the Formula SAE competition is to advance students' design skills and project management skills by participating in a design competition. To give perspective on the aims of this automotive design competition, we gave a brief overview of the other popular racing competitions and how they compare to FSAE. This included Formula 1, NASCAR, Indycar, autocross, rally, and drag racing. For each racing competition we showed a short, muted video clip while talking about the similarities and differences to the Formula SAE competition.

Next we dove into the individual events at a Formula SAE competition. Beginning with a high level overview, first there is the tech inspection, which is required in order to proceed in the competition. The events break down into static events, which are presentation based, and dynamic events, where the car is driven. Each event has different point values that can be earned based on how the car performs. During the overview of this breakdown, we presented the point distribution by event. Then we briefly described the tech inspection, which includes tilt, sound, braking, and driver egress.

Before moving onward in the presentation, we took five minutes to distribute and discuss a handout that covered many of the key rules for each subsystem of the vehicle. This double-sided handout can be found in the export folder. Then we went over the static events, which include the design judging, business presentation, and cost report. Following this, we talked about the dynamic competition events, including acceleration, skidpad, autocross, endurance, and fuel efficiency. The last thing that we shared from the presentation was a diagram of where all of these events occur at the Michigan International Speedway (MIS).

After the presentation was over, we stopped and answered questions relating to the content. Then we proceeded to describe the activity and allow the attendees to group themselves up and start working. The challenge presented was to design an impact attenuator and safety equipment for a 1:10 scale model of the most recent Formula SAE frame. The materials available to each student are listed in table 10 below. There were six groups.

Table 10: Activity 1 Materials

Item	**Quantity per Group**	**Total Quantity**	**Estimated Ext. Cost**
3D printed frame	1	6	$17
Small car	1	6	$20
Grocery bag	1	6	$0
Small ziplock bag	1	6	$3
Egg	1	6	$1
Foam Sponge	1/2	3	$5
Cotton balls	10	60	$2
Chopsticks pack	1	6	$0
Nitrile glove	1	6	$0
Straws	2	12	$0
Plastic-ware set	1	6	$0
Painters Tape roll	0	1	$1
Spool of string	0	1	$2
Scissors	0	3	$0
Hot glue	0	3	$0

The activity was broken into three parts: a building session, a design presentation and review, and testing. During the building presentation, the physics equations for calculating a rough estimate of the necessary compression of the impact attenuator were provided. Part of the way through the session lunch was provided. At the conclusion of the building session, each team was given several minutes to present their design and receive feedback. We provided several questions that guided their presentation of their design process. The last portion, the testing, was done alongside Riley hall on one of the stairs. A few pieces of plywood were laid over the stairs, and a wall was set up at the bottom for the cars to hit. Each car was rolled from a distance of 10 feet. Almost every single car survived the first test, so we then extended the ramp and tried for longer distances until only one egg remained. Figure 5 is a picture of the setup where the cars were tested.

Figure 5: Seminar I Test Ramp

At the end of testing, we rewarded everyone with a custom laser-cut keychain and requested feedback via the survey found in Appendix A. The results of the survey data can be found in Appendix B. Each team was allowed to take their vehicle home. The last thing we did was introduce the topic of our next seminar and give a short summary of how to get more involved with WPI's SAE Team.

Seminar II: Engine Basics

The second seminar covered the basics of internal combustion engines. This ranged from the mechanical and chemical workings of such as well at their applications in both road and FSAE vehicles. The structure of this seminar is shown in the following table.

Table 11: Seminar II Structure

Content	**Duration**	**Time Start**	**Time End**
Informal discussion and coffee while people show up	10 minutes	11:00 am	11:10 am
Presentation	30 minutes	11:10 am	11:40am
Engine Assembly Activity	45 minutes	11:40 am	12:25 pm
Lunch	30 minutes	12:25 pm	12:55 pm
Presentation	60 minutes	12:45 pm	1:45 pm
Activity: Engine Simulation	30 minutes	1:45 pm	2:15 pm
Test Engines	15 minutes	2:15 pm	2:30 pm

As in the prior seminar, this one also began with informal discussion with attendees who arrived early which allowed us to better learn names and start to recognize returning faces to our presentations. Everyone was then directed to the front of the lecture hall as the presentation began with another introduction of the presenters. The presentation then proceeded to go on about the very basics of what an engine is, as in what the job of the engine is, as well as where in the car they are typically located and how they tie into the drivetrain as a whole. Following, the most common four-stroke cycle in a piston style combustion engine was discussed as it most relevant to FSAE being the only type of engine we are allowed to use. We did not touch upon two-stroke engines as we deemed them too confusing for someone with no background whatsoever with internal combustion engines. After explaining normal engine configurations with regards to cylinder placement we briefly touched upon some less common engine types; Wankel rotary and engines in a piston configuration operating on the diesel cycle.

The presentation transitioned into describing the components of an internal combustion engine. These components were divided into two groups; top end and bottom end. This is generally is how the components of an engine are divided up in the automotive industry, so it not only gives an idea of industry standards but also makes the components easy to follow throughout the presentation. The path of starting with the bottom end was followed as this included the main parts that make the engine function. Our grouping of bottom end parts included; engine block, crankshaft, pistons, connecting rods, oil pan and also included an explanation of how a radiator works. Each one of these components had its own slide which explained the common material the component was made of, its purpose and position in the engine itself, as well as some common variations of said component. The grouping of the top end parts was as follows; cylinder heads, intake and exhaust valves, spark plugs, injectors, camshafts, timing, intake manifolds, and finally exhaust systems. Effectively the same descriptions of the roles, variations and materials of such were provided.

This portion of the presentation transitioned well into our first activity. This was a different style of activity as it had three stations that the attendees rotated through, allowing a large amount of content to be absorbed in the time allotted. The stations had no order in particular but the “first” activity will refer to the disassembly and assembly of a 600cc Honda CBR 600rr sport motorcycle engine (Figure 6). This engine is an inline four-cylinder configuration with dual overhead cams, which was described in the presentation.

The “second” station was a similar assembly and disassembly with the exception of the engine being a Briggs and Stratton (Figure 7) 250cc engine normally found in a lawn mower or SAE Baja vehicle. This particular engine was a single cylinder with pushrod valve actuation. The Briggs and Stratton engine differed from the CBR engine in that it had full mechanical control with air cooling as opposed to electronic engine control and water cooling. Presenting two types of engines allowed attendees to see both ends of the technological spectrum when it comes to internal combustion engines as well as seeing multiple configurations.

The “third” activity went a little more into the specifics of a single component found in nearly all piston internal combustion engine: the camshaft. This activity went over the basic specifications of camshafts and how they affect the performance of the vehicle. It also had a hands-on component where attendees were able to theoretically select a camshaft for a 350 cubic inch Chevrolet v8 engine. Four options were presented with only one of the camshafts being correct for the given application, and an explanation was given as to why the others were not optimal.

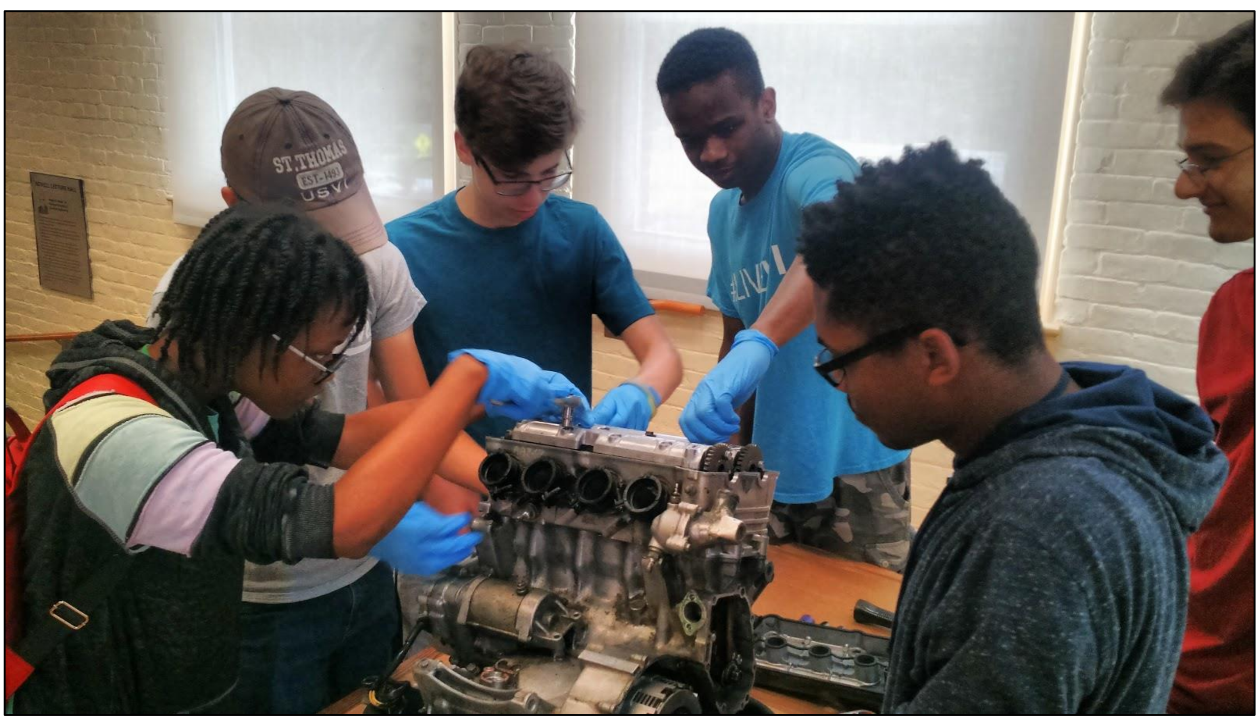

Figure 6: Attendees hard at work on the CBR 600 engine

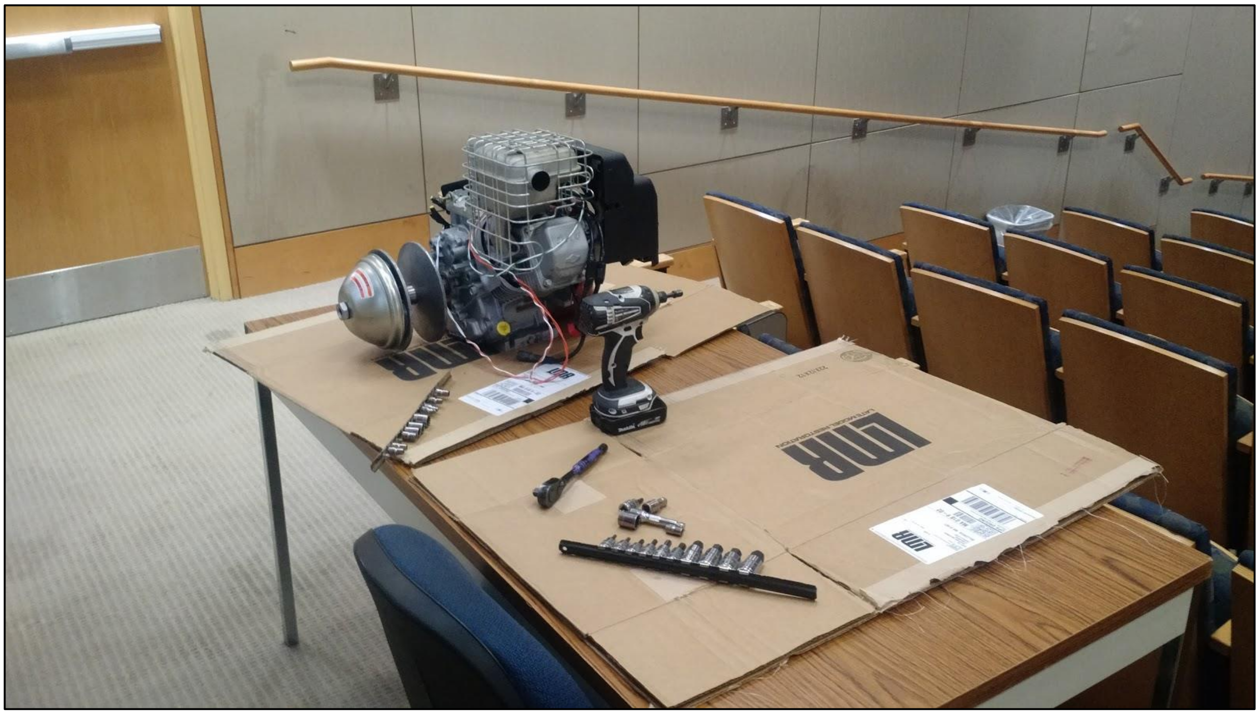

Figure 7: Briggs and Stratton engine ready for students

The activity ran slightly over the original time allotted so there was a slight overlap with the lunch we provided which then proceeded to slightly overlap the second half of the presentation. The second half of the presentation went into more detail about the physics and chemistry involved in an internal combustion engine. This started with a basic explanation of different types of fuel used ranging from traditional gasoline to alcohols and diesel fuel. Advantages and disadvantages of each type of fuel were discussed involving the energy contained within, knock resistance and their effects on vehicle performance. This progressed into a brief discussion of torque and horsepower, how they are related and their application with regards to engines. Next was discussed ways to increase horsepower and torque through the use of power adders, their advantages and drawbacks, as well as their applications in a vehicle. This allowed us to easily progress into talking about both electronic and mechanical engine controls as they control the parameters above. Finally all of this information was tied together and the relation of it to FSAE was discussed.

Our second and final activity was then explained as it was creating an FSAE rules compliant engine in the video game, *Automation,* which has a very accurate engine simulation feature within. The rules that the attendees had to follow were: engine displacement limited to 710cc's, and to simulate the restrictor they required to run the "Standard Intake" intake manifold as it is the most restrictive in the game. Although their options were unlimited otherwise, they were scored on the following categories; performance, weight, reliability, throttle response, smoothness, loudness, fuel efficiency, material cost, engineering time, peak HP, and peak torque. The simulation feature produces values for all of these categories, and the three teams were awarded points accordingly.

Seminar III: Manufacturing

Our third seminar covered manufacturing processes in general, and then focused on those used in FSAE. We started out by covering the whole process of designing and building a car and went into more specifics on each process used during each phase of the process. The schedule for the third seminar was as follows:

Table 12: Seminar III Structure

Content	**Duration**	**Time Start**	**Time End**
Informal discussion and coffee while people show up	10 minutes	11:00 am	11:10 am
Presentation	30 minutes	11:10 am	11:40am
SolidWorks Assembly Activity	45 minutes	11:40 am	12:25 pm
Lunch	30 minutes	12:25 pm	12:55 pm
Presentation	60 minutes	12:45 pm	1:45 pm
Activity: Drilling and Tapping	30 minutes	1:45 pm	2:15 pm

The first step was covering design, including CAD, CAM, FEA, and validation. Next, we put together a hands-on activity for students to do which involved putting together a model of a functioning U-joint in SolidWorks CAD software.

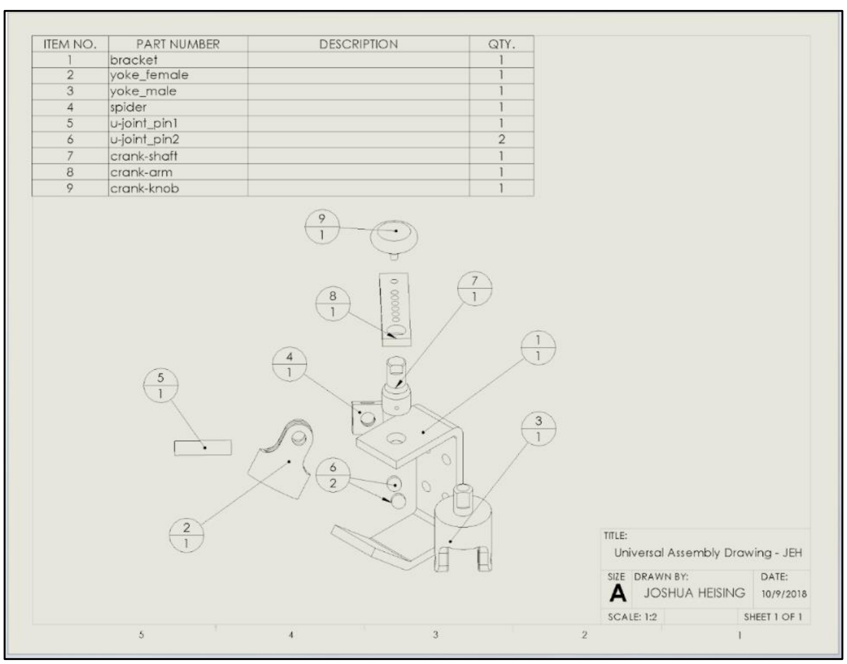

Figure 8: U-Joint Assembly Drawing

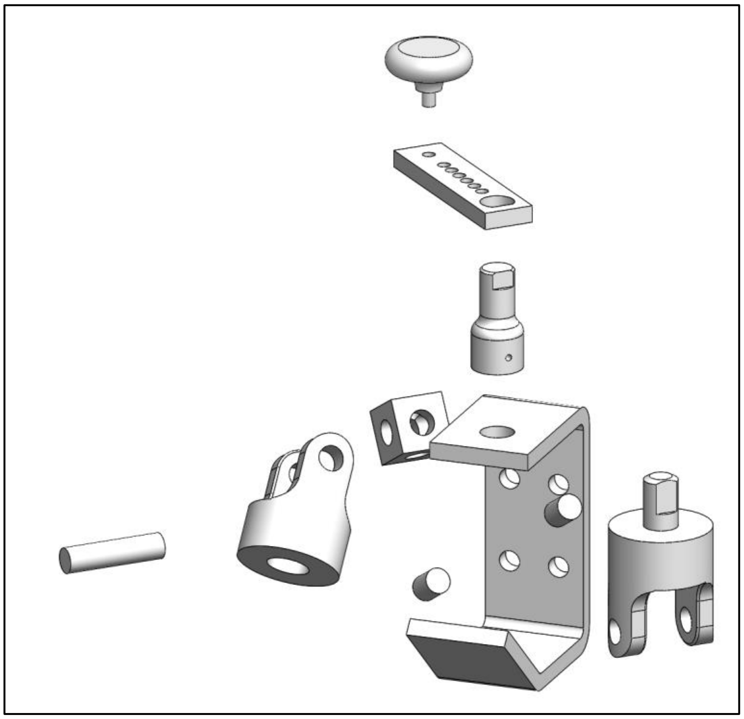

Figure 9: U-Joint Assembly Exploded View

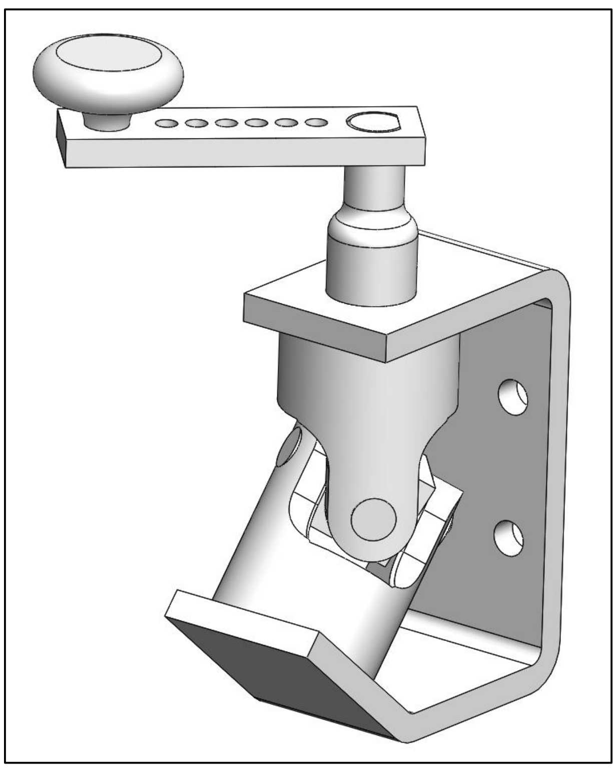

Figure 10: Assembled U-Joint

Students needed to add the right mates and connections to allow the u-joint to function in a realistic way and prevent unrealistic motion. It was evident that there were different skill levels in the room, but we were able to tend to everyone by having several of us go around the room and check in. This way, students who needed extra help were given assistance and students who already finished were given additional problems and challenges.

While we were in the computer lab, we gave students the basic user quiz so that they could become basic users for the shops on campus. We gave a brief presentation on shop and tool safety to cover what they needed to know for this quiz.

After students completed the quiz, we served everyone lunch and began the second portion of the presentation. This part of the presentation covered:

- The differences between additive and subtractive manufacturing
- Different tools and shop machinery
- The manufacturing processes used on a FSAE car

We discussed the operation of cutting tools such as band-saws, chop saws, drills/drill presses, taps and dies, and shears. As for machine shop machines, we went over the differences between milling machines and lathes, how they work, and the differences between manual machining and CNC machining. Once the operation of these various tools had been covered, we moved into the processes which would be used on an FSAE car in the approximate order they would be used. This started with discussing the manufacture of the frame including the cutting, coping, and welding of tubes and heat treatment (or normalization) of the frame. Next, we explained in greater detail how machining works and how it relates to our suspension system which has many machined parts including rockers and uprights. Once the machining of the suspension was covered, we went over the operation of a press and how we press bearings into our suspension. The operation of a bending brake and how it applies to forming our sheet metal firewall was covered. Next, we discussed the operation and different kinds of laser cutters and 3D printers and how they relate to our steering system parts. Our last manufacturing process covered was the lay up of composites as this is the primary method used to make our body work every year.

The second and final activity for this seminar involved learning to properly drill and tap holes to accept hardware. We gave students a previously prepared CNC machined smiley face. Before the activity, we showed them a video on how the part was machined on a lathe and CNC mill. The part was designed so that the eyes of the smiley face were spot drilled. This allowed the students to drill out the eyes on a drill press and then use a hand tap to make threads to insert screws. Overall, this activity covered how to use the right size drill bit and proper tap to ensure the fit of a specific size of hardware. This seminar also ended 15 minutes late in order for us to give everyone a chance to drill and tap holes.

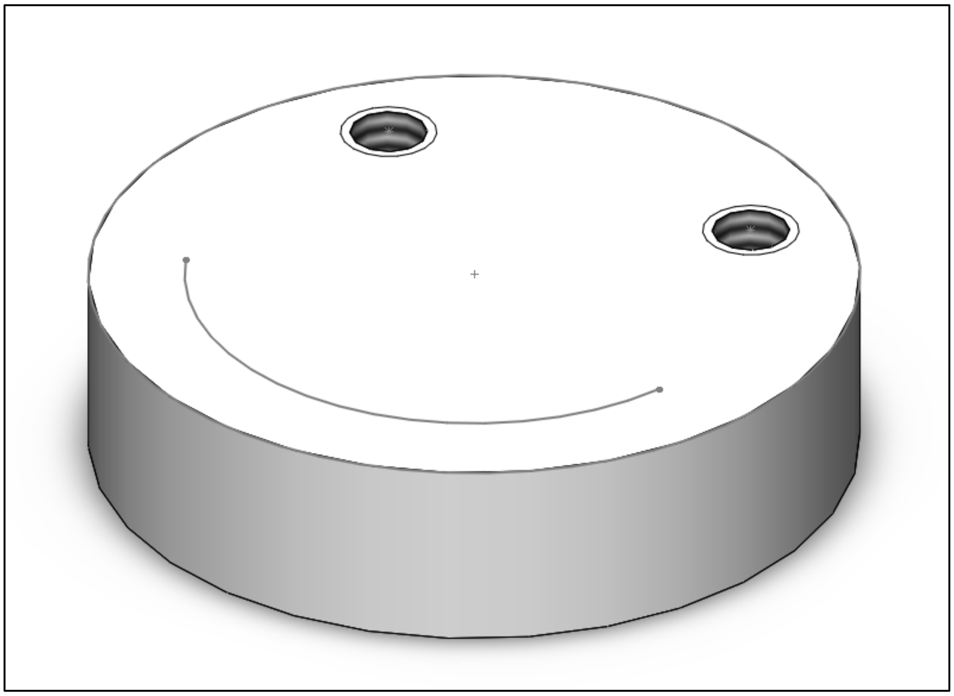

Figure 11: Smiley Face CAD Model

Seminar IV: Electrical Systems and Aerodynamics

Our fourth seminar covered an introduction to electrical systems as well some basics of aerodynamics. This included topics ranging from what circuit components like a resistor do, to understanding most common aerodynamic elements in a Formula SAE car. We also covered an explanation of how to troubleshoot automotive electrical systems. Additionally, we had Professor Kenneth Stafford as a guest speaker at this event, talking about the electrical systems in his new Audi S8, as well as other cars he has owned.

Table 13: Seminar IV Structure

Content	Duration	Time Start	Time End
Informal discussion and coffee while people show up	10 minutes	11:00 am	11:10 am
Presentation: Stafford guest speaker	45 minutes	11:10 am	11:55am
Lunch	25 minutes	11:55 am	12:20 pm
Presentation: Electronics	30 minutes	12:20 pm	12:50 pm
Activity: Electrical Diagnosis, Soldering, Simulation	45 minutes	12:50 pm	1:35 pm
Presentation: Aerodynamics	15 minutes	1:35 pm	1:50 pm
Activity: Wind Tunnel Testing	40 minutes	1:50 pm	2:30 pm

The electronics section of the seminar followed. This rather short component touched upon the basic purposes of the electronics found in a typical automobile. This included some common sensors broken down into categories such as control or feedback sensors and sensors that simply monitor a given value within the vehicle and report it to the operator. The electrical presentation concluded with a simple explanation on how to diagnose electrical problems in a typical car.

The activity was similar to the activity in Seminar II where there was three different stations; Electrical Diagnosis, Soldering and Circuit Simulation. At the electrical diagnosis station we had one of our own older FSAE cars with “electrical problems”. This consisted of a blown fuse, an unplugged battery and an unplugged fuel pump. Attendees were shown how to use a multimeter to measure voltage and continuity in a wire in order to diagnose these issues and make the vehicle start again. Each group solved one of the three faults in a different order, so each group had a slightly different experience at this station. At the soldering station attendees were shown how two wires can be securely attached. This was accomplished by having attendees use a wire stripper to strip two ends of a short section of wire, and then solder those two ends together after bending the wire into a bracelet sized loop. Finally, the electrical circuit simulation activity used an online simulator, however due to computer issues only a limited number of people participated.

The second half of the presentation was focused on the most common aerodynamic devices found in both FSAE and on-road cars. This started with an explanation of Bernoulli’s principle and how it relates to downforce and the performance advantages as a result. Then a short explanation of each individual aerodynamic device was presented with its purpose as well as pros and cons. This was followed by a series of case studies of both real world race cars as well as some top FSAE competitors. The main features of each vehicle were discussed along with a short blurb about the history of said vehicle. We kept this section of the presentation relatively short to allow for extra time for the aero activity.

This seminar ended with our aero activity: a wind tunnel test. The attendees were divided up into three groups and were provided a model frame similar to the frame from seminar I. They were also given some basic craft materials (paper, cardboard, hot glue, etc.) to make an “aerodynamics package” for their frames. The only restriction on the design was fitting into our homemade wind tunnel. They were scored on the weight of their vehicle as well as the amount of downforce at each of the three speeds wind-speeds. Our wind tunnel, was very easy to build. It consisted of a three speed box fan and a cardboard tunnel. A cardboard structure arranged in a grid pattern was placed between the fan and the tunnel in order to straighten the flow of air resulting in relatively laminar flow across the models placed inside. Approximately two feet after the grid was a section of the tunnel with an acrylic panel for viewing and loading the vehicles as well as viewing the small kitchen scale that was able to measure the downforce that was produced. With these aero packages approximately thirty to forty grams of downforce was standard at the high fan speed. An example car being tested can be seen in Figure 12 below.

Figure 12: Testing Aerodynamics

Seminar V: Vehicle Dynamics

The fifth educational day covered an introduction to vehicle dynamics, including suspension design, and frame design. The pre-lunch lecture session featured the second guest speaker of our series, Bill Gendron. This was followed by lunch, after which the presentation began. The first presentation of the seminar covered the basics of frame and suspension design. This was followed by an activity in frame design, where students made model frames and their torsional rigidity was tested. The seminar was concluded with a presentation on tires. The times for each segment are provided in Table 5 below.

Table 14: Seminar V Structure

Content	**Duration**	**Time Start**	**Time End**
Informal discussion and coffee while people show up	10 minutes	11:00 am	11:10 am
Guest Speaker: Bill Gendron	40 minutes	11:10 am	11:50
Lunch	25 minutes	11:50 am	12:15 pm
Presentation: Suspension	40 minutes	12:15 pm	12:55 pm
Activity: Frame Design & Torsion Testing	60 minutes	12:55 pm	1:55 pm
Presentation: Tires	25 minutes	1:55 pm	2:20 pm

Bill is an aerospace engineer by trade. After twenty years at Pratt & Whitney he left to become a full time race engineer. Bill's company Small Fortune Racing campaigns a number of exciting racing cars on the east coast, including in-house custom built prototypes for both road course racing and autocross applications. Bill also has a Riley Daytona Prototype, seen in Figure 13, which is the most prominent endurance racing prototype in the United States.

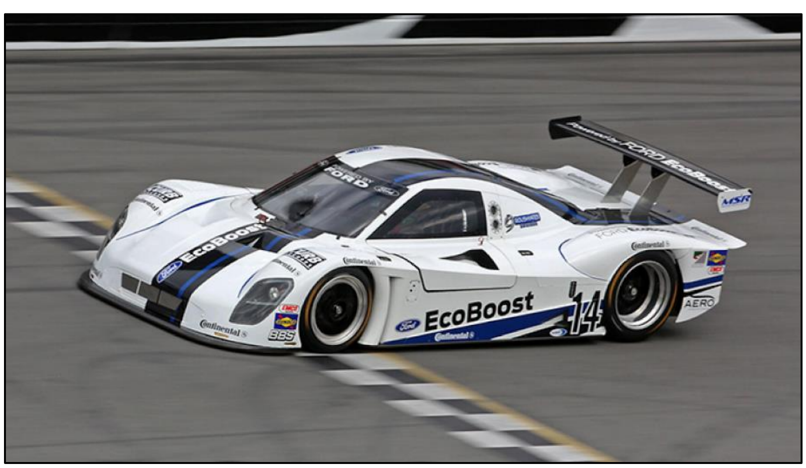

Figure 13: Riley Daytona Prototype

In our seminar, he discussed the changes he has seen in his almost 50 years of racing. Since he started racing in 1970, there have been many new developments in racing technology, and almost as many rules to remove said developments. One of the most effective of these methods was using a leaf blower to suck air out from under the car, greatly improving downforce without the added drag penalty associated with wings. This was very quickly banned by every sanctioning body.

After Bill's presentation, a pizza lunch arrived for seminar attendees. There were a few minutes of question and answer after the talk. Then, the WPI SAE MQP team took Bill to the lab, where they showed him the current progress on the car. He was able to provide some useful insight towards the design of this year's car. While that happened, the SAE IQP team began the main presentation.

The first topic was basic vocabulary related to vehicle dynamics, beginning with an overview of the relevant parts. These included the uprights, the hubs, the ball joints, the control arms, as well as the springs and dampers. We also talked about the importance of the chassis, which largely serves as a bracket to hold the aforementioned items. One of the largest factors in determining the dynamic response of a vehicle is the torsional rigidity of the frame, as the frame is required to react all of the loads generated by the tires. A frame with insufficient rigidity will feel sloppy and unpredictable to the driver. In professional motor racing, complicated test rigs are created to test torsional rigidity as pictured in Figure 14 below.

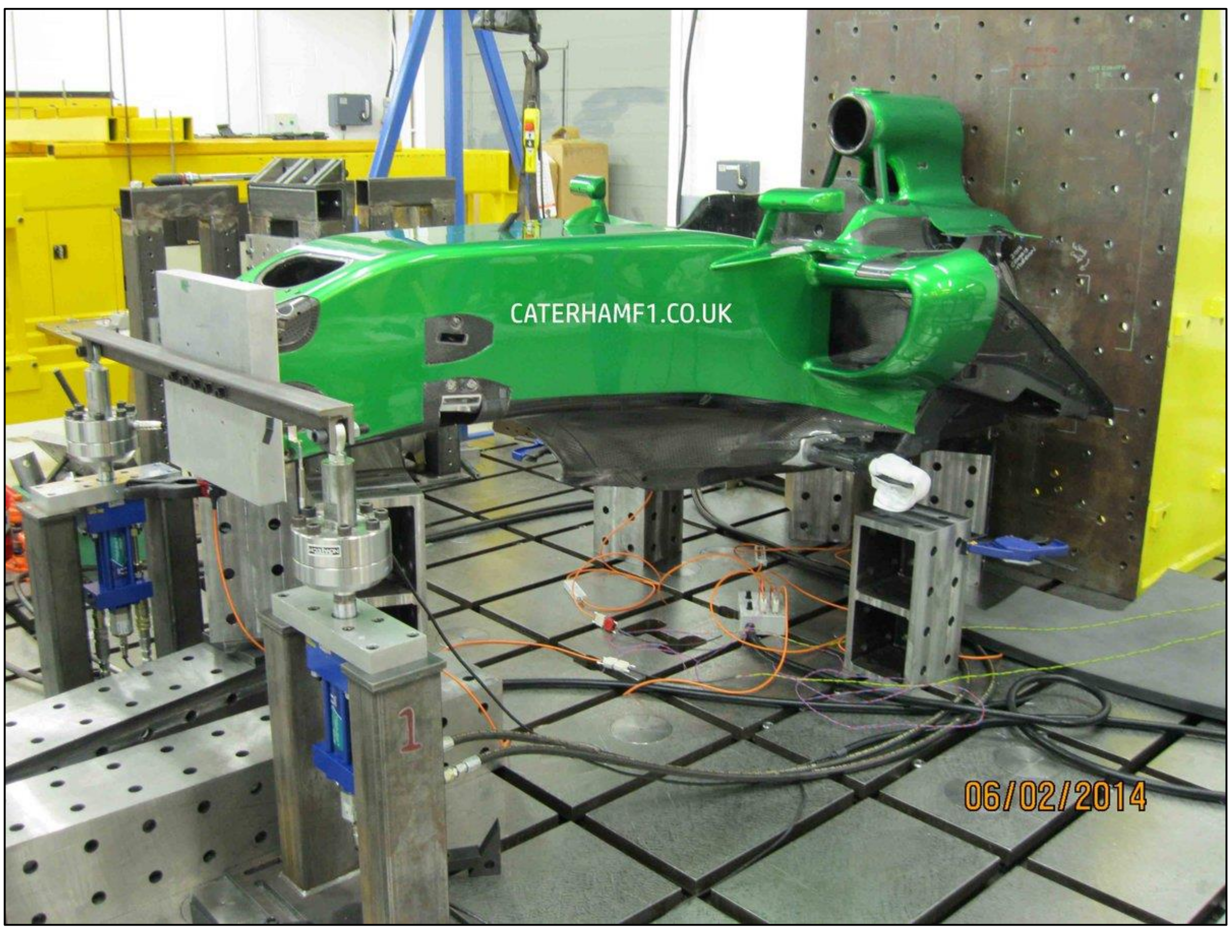

Figure 14: Chassis Stiffness Test Jig

The presentation then moved on to the geometric relationships that characterize the design of the suspension. These include the wheel geometry angles, such as camber and toe. Also discussed was the kingpin axis and the implications of its projections. The side-view projection of the kingpin axis determines the castor angle. This defines the mechanical trail of the car, which is responsible for generating self-aligning torque at the steering wheel. The front-view projection of the kingpin axis determines the kingpin inclination angle. This angle defines the scrub radius, which has a large effect on the steering feel of the car. Another important aspect of steering design is the Ackermann steering ratio. This describes the relative angles of the front wheels while cornering.

The activity for this seminar was to create a frame made out of drinking straws and glue. The frames were each torsion tested in a miniature test rig set up in the classroom. Students were broken up into small groups, and each was given two bulkheads, one front and one rear. These bulkheads were designed to simplify the torsion testing process, featuring screw holes at the front bulkhead to fixture the frame, and a mount for a Popsicle stick at the rear. This functions as a lever arm to apply the torque to the frame. Fishing weights were attached to the end of the Popsicle stick to generate this torque.

After the activity, there was another presentation, this time focusing on tires. This covered different types of tires and their applications. The presentation also discussed tire testing in its many forms, from on-track testing to laboratory analysis. WPI is a member of the Tire Test Consortium, which is a group of Formula SAE teams that pool resources to buy lab testing of tires. Testing takes place at the Calspan TIRF facility in Buffalo, NY. Generally speaking, the consortium tests every tire that is relevant to the competition in a number of ways. This data is then provided to teams, along with a few ideas on how to use it.

Seminar VI: Driver Strategies

Our sixth and final seminar covered driving techniques, skills, and race performance. This included discussing driving techniques for fast driving such as left-foot-braking, racing lines, trail-braking, shifting etc. For the hands-on activity, participants were given the opportunity to drive one of the past cars that the club took to competition in Michigan in 2015.

Table 15: Seminar VI Structure

Content	**Duration**	**Time Start**	**Time End**
Loading cars/cones to go to test location	30 minutes	9:00 am	9:30 am
Driving to and setting up track	1.5 hours	9:30 am	11:00 am
Presentation followed by drive to test track	1 hour	10:15 am	11:15 am
Course walk and explaining elements	15 minutes	11:15 am	11:30 am
Taking turns driving (12 people)	10 minutes/per.	11:30 pm	1:30 pm
Lunch (eat while others drive)	1 hour	12:00 pm	1:00 pm
Pack up and return to WPI	1 hour	1:30 pm	2:30 pm

The day started off with some minor hiccups, when neither one of the cars we had planned to bring would start in the morning, as well as finding a broken suspension tab. This led to us leaving a few minutes late, after welding the tab back on and getting both cars' batteries charged. 3 of us went to the test location at Milara Inc. to set up, while 2 remained at WPI to present the seminar material, and then get everyone to Milara afterwards. The presentation covered all of the safety aspects of driving an SAE car, including protective gear, and how to turn the car completely off, as well as various techniques for driving fast, such as how to determine a racing line, the best times to brake and accelerate, and common mistakes that new racers make. Finally, we covered common elements seen in most autocross events, in order to familiarize new members with what they would see on the course later in the day.

While the group of two was presenting, the other three went to Milara to set up a course and prepare, so that people could start driving as soon as they arrived. Figure 15 shows a rough sketch of the course that we set up, as well as a rough racing line. When designing the course, we focused on including all of the elements that one would typically see at a regular autocross event, like slaloms, boxes and offset gates. Additionally, we attempted to make a relatively slow course that would keep drivers moving slowly, giving everyone a chance to familiarize themselves with the car, while also being open enough to be fun to drive. Attendees were required to wear all of the common safety gear, including a fire suit, helmet, and wrist restraints.

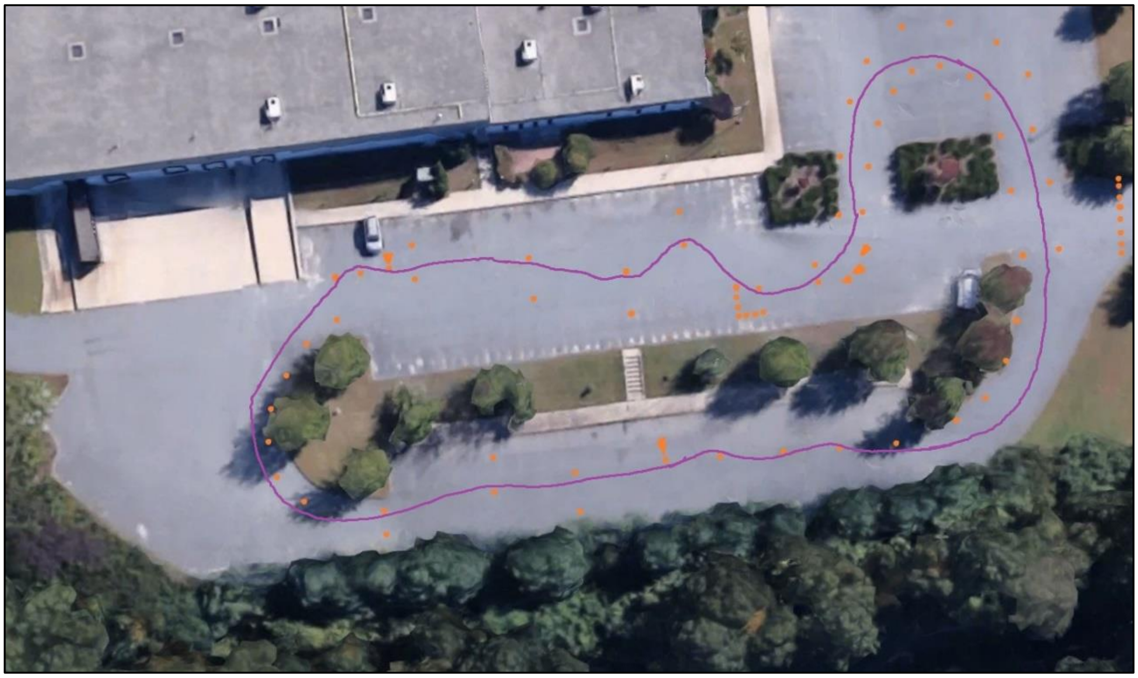

Figure 15: Race-course With Ideal Line