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A Three-Semester Mechanical Engineering Capstone Design Sequence Based on an SAE Collegiate Design Series

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Abstract

Mechanical engineering students at Lawrence Technological University complete a five-credit hour capstone project: either an SAE collegiate design series (CDS) vehicle or an industry-sponsored project (ISP). Students who select the SAE CDS option enroll in a three semester, three course sequence. Each team of seniors designs, builds, and competes with their vehicle at one of the SAE CDS events. Despite some strong finishes in the past, overall competition performance has recently declined and student exit interviews indicated dissatisfaction with the course sequence. This work examines a complete course sequence overhaul focused on improving student design, collaboration, and communication skills; integration of the SAE CDS events into the curriculum; and faculty advisor involvement in the classroom. Initial assessment of the proposed course modifications is performed using faculty advisor observation, student surveys, and direct assessment of student work.

Introduction

Senior students enrolled in the B.S. Mechanical Engineering program at Lawrence Technological University (Lawrence Tech) complete a capstone project prior to graduation. These capstone projects serve as a summative assessment, bringing together machine design, thermo-fluids, manufacturing, and mechatronics topics into a real-world design experience. Relative coverage of these topics depends strongly on the particular design project selected.

Currently, the Mechanical Engineering department offers two tracks for capstone projects: competition projects from the SAE Collegiate Design Series (CDS) and industry-sponsored projects (ISPs). ISPs represent time-sensitive real-world problems brought to the department by industry partners. Students complete five (5) credit hours over two semesters and, depending upon the alignment of their individual progress and the arrival of new projects, may be involved with a single project or parts of two different projects. For a two-semester project, the first semester includes research into the problem, design of a solution, validation of the design using appropriate software tools or calculations, and a report to the industry partner detailing the proposed design. The second semester includes fabrication of a working prototype validation of the prototype, and a presentation of the final design and prototype to the industry sponsor. Each student submits monthly progress reports and the team is responsible for a comprehensive report each semester as well as a poster and oral presentation to ME faculty and the departmental Industry Advisory Board (IAB). Examples of past ISP projects include a fluid-powered gantry crane[1] and a decoupler for driveline dynamics[2].

Competition projects include Baja SAE, Formula SAE, Formula Hybrid, SAE Aero Design, and SAE Supermileage. The Mechanical Engineering Department at Lawrence Tech has found that the SAE CDS is an excellent program for senior projects. Students who select the SAE CDS option enroll in a three course sequence. Each team of seniors designs, builds, and competes with their vehicle at one of the SAE CDS events. While some specific aspects of the rules may change for each competition year, the overall objectives and outcomes of these competitions change little from year to year, resulting in the capstone design projects being more structured than ISPs. Though each team is required to build a new vehicle, previous student team vehicles are available for students to reference which transforms the project from an entirely new design into a process of continual improvement. Timelines are based on SAE deliverables and competition dates which prevents extensions or spillover from semester to semester.

Traditional engineering curricula face the challenge of finding a way for the students to integrate the theory they learn in the classroom to real life, let alone the integration of the different disciplines of engineering. In competition projects, such as the SAE CDS, students must conceive, design, build, test, develop and compete a race car. This provides the student with a real-life work environment and highlights the need for integration of previous theoretical knowledge. Besides the technical aspects, the group of students must secure funds by contacting sponsors and negotiating with them. The projects provide a good motivation for the students and an excellent tool for assuring knowledge integration, team work, management experience, and self-confident students, plus a way to obtain funds for investment into quality teaching[3]. Intercollegiate design projects are a great means to engage students in engineering design projects beyond the curriculum, where they put their coursework into practice. Design competitions give the students hands-on experience as well as build student enthusiasm. The experience of designing, building and testing a vehicle gives the students a real world engineering experience[4].

Capstone projects, although they are different than the competition projects as far as the competition element is concerned, still provide engineering students the opportunity to solve real-world, open ended engineering projects, and have been highly regarded as important learning activities. A significant number of institutions are recognizing the advantages of involving industrial sponsored projects into their curricula. Industry can support engineering education by helping to find educationally viable projects and provide funding to offset additional resources needed for this type of educational experience. According to a survey performed by Todd *et. al.*, the departments believe their capstone course was very beneficial to their students, with a rating of 8.6 on a 10 point scale[5].

In recent years, competition performance by Lawrence Tech SAE CDS teams has been sporadic. For example, the Lawrence Tech Formula Hybrid team placed 2nd in 2013 and 2014 but did not pass technical inspection in 2015. Despite some strong finishes in the past, overall competition performance has recently declined and student exit interviews indicated dissatisfaction with the course sequence. Some universities have come to the conclusion that use of SAE projects as class credit inhibits performance at competition[6]. In addition, student and faculty identified curricular weaknesses including misalignment of course objectives and grading system and poor time management.

In this work, the three semester capstone design sequence at Lawrence Tech is examined, including course modifications that were made to address identified weaknesses. These modifications include a revised syllabus to better utilize in-class time, use of team-teaching to include faculty advisors in the classroom, revised deliverables based on student work rather than presentation, and milestone-based scoring for the students' project execution portion of grading system. A longitudinal study of student work, scored with a common rubric, is undertaken and in-progress student work samples are used to validate continued implementation of the proposed modifications.

The organization of this paper is as follows. First, the state of SAE competition-based capstone design projects at Lawrence Tech is reviewed. Next, weaknesses in the existing curriculum are identified. Solutions to the identified weaknesses are proposed. Finally, in-progress student work samples are reviewed to validate the proposed solutions and the work is concluded.

SAE Competition Projects at Lawrence Technological University Prior to 2015-2016

The Mechanical Engineering department at Lawrence Tech has employed a three semester sequence for capstone design for several years. The course content was unchanged between Fall 2011 and Spring 2015. A three semester capstone sequence was chosen because Lawrence Tech College of Engineering places a high importance on the capstone design experience based on faculty and industry advisory board input. A Spring semester project introduction class gives the students all of the needed project management tools to use and prepare over the summer for a rapid startup and action-oriented subsequent Fall and Spring semester project. This is especially critical for competition team senior project activities.

The sequence consists of three separate courses across three semesters: Introduction to Engineering Projects, Engineering Projects 1, and Engineering Projects 2. Introduction to Engineering Projects was intended to introduce students to the CDS projects while teaching matching engineering specifications to customer requirements, prototyping, product testing & evaluation, and project management. Engineering Projects 1 was intended to cover the vehicle design while teaching quality function deployment, failure modes and effects analysis, sustainability, and budgeting. Engineering Projects 2 was intended to cover vehicle fabrication and testing. Excluding summer semesters, Introduction to Engineering Projects and Engineering Projects 2 were offered in the Spring while Engineering Projects 1 was offered in the Fall, as shown in Table 1. The schedule aligns well with CDS timeline because the students need to get vehicles ready for the competitions which usually happen in late Spring or early Summer.

Table 1 – Course offering schedule.

	Credits	Spring	Fall
Intro Engineering Projects	1	X	
Engineering Projects 1	2		X
Engineering Projects 2	2	X	

Each team was headed by a faculty advisor while another faculty served as the course instructor. The advisors and instructor are shown in Table 2. Each faculty advisor received teaching release time equivalent to half of a three-credit class per semester. The course instructor received five-credits of teaching load per year.

Table 2 – SAE competition team advisor and course coordinators.

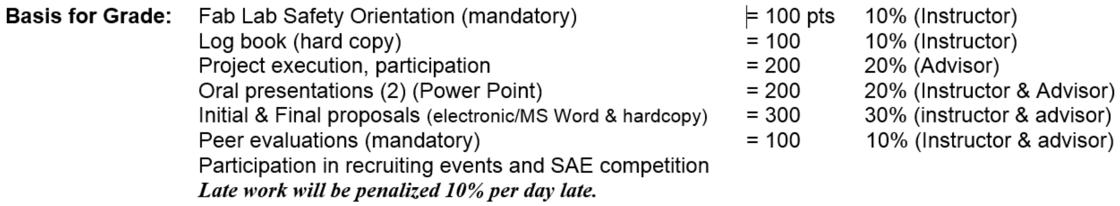
Advisor	Team	Years of Experience
A	Formula SAE	1
F	Formula Hybrid	7
G	SAE Aero Design	13
L	SAE Supermileage	2
M	Baja SAE	4
Y	Course Instructor	5

Course content for the three course sequence was assumed to be taught as-needed in team meetings and during team work sessions by the faculty advisor. Therefore, scheduled classroom time for the courses was used only when needed for class-wide administrative tasks. Table 3 lists the course classroom sessions. During unused classroom times, the class did not meet, but students were expected to meet with their faculty advisors and work on their projects/vehicles.

Table 3 – Course content prior to 2015-2016.

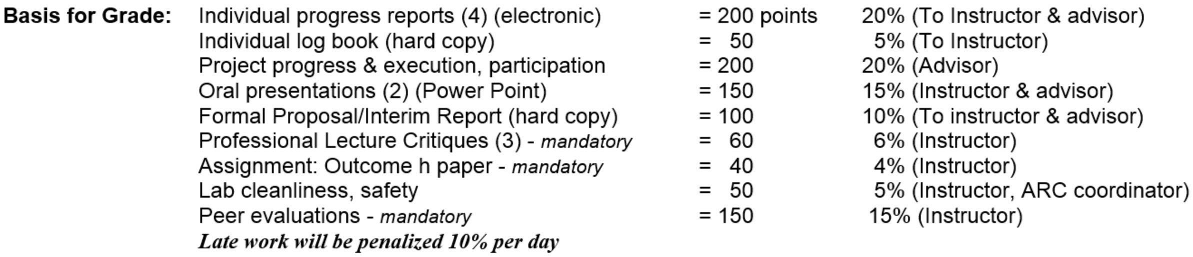
Week	Intro Engr Proj	Engr Proj 1	Engr Proj 2
1	CDS Overview	Introduction	Syllabus
2	Syllabus, Safety	Proj 1 Lecture	-
3	Fabrication Lab Safety	-	-
4	-	-	-
5	Rubrics, Logbooks, Proposal	Team Presentations	-
6	-	-	-
7	-	-	-
8	-	Peer Evaluations	-
9	Peer Evaluations	-	Peer Evaluations, Ethics
10	-	-	-
11	-	-	-
12	EdgeCam Workshop	-	-
13	-	-	-
14	Siemens NX Workshop	-	-
15	Design Proposal	Design Review	Oral Presentation

Student grades for the three course sequence were determined by individual progress reports and log books, team reports and presentations, peer evaluations, lab cleanliness, ABET-related assignments, and “participation and execution”. These factors are shown in Figure 1, Figure 2, and Figure 3. Rubrics were used for scoring progress reports, log books, team reports, and team presentations. However, each faculty advisor used his/her judgement in assigning points for “participation and execution”.



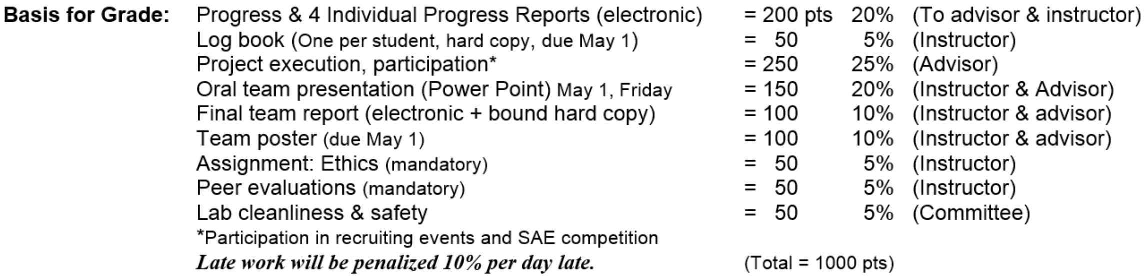
Basis for Grade:	Fab Lab Safety Orientation (mandatory)	= 100 pts	10% (Instructor)
	Log book (hard copy)	= 100	10% (Instructor)
	Project execution, participation	= 200	20% (Advisor)
	Oral presentations (2) (Power Point)	= 200	20% (Instructor & Advisor)
	Initial & Final proposals (electronic/MS Word & hardcopy)	= 300	30% (instructor & advisor)
	Peer evaluations (mandatory)	= 100	10% (Instructor & advisor)
	Participation in recruiting events and SAE competition		
	Late work will be penalized 10% per day late.		

Figure 1 – Grading scheme for Introduction to Engineering Projects prior to 2015-2016.



Basis for Grade:	Individual progress reports (4) (electronic)	= 200 points	20% (To Instructor & advisor)
	Individual log book (hard copy)	= 50	5% (To Instructor)
	Project progress & execution, participation	= 200	20% (Advisor)
	Oral presentations (2) (Power Point)	= 150	15% (Instructor & advisor)
	Formal Proposal/Interim Report (hard copy)	= 100	10% (To instructor & advisor)
	Professional Lecture Critiques (3) - *mandatory*	= 60	6% (Instructor)
	Assignment: Outcome h paper - *mandatory*	= 40	4% (Instructor)
	Lab cleanliness, safety	= 50	5% (Instructor, ARC coordinator)
	Peer evaluations - *mandatory*	= 150	15% (Instructor)
	Late work will be penalized 10% per day		

Figure 2 – Grading scheme for Engineering Projects 1 prior to 2015-2016.



Basis for Grade:	Progress & 4 Individual Progress Reports (electronic)	= 200 pts	20%	(To advisor & instructor)
	Log book (One per student, hard copy, due May 1)	= 50	5%	(Instructor)
	Project execution, participation*	= 250	25%	(Advisor)
	Oral team presentation (Power Point) May 1, Friday	= 150	20%	(Instructor & Advisor)
	Final team report (electronic + bound hard copy)	= 100	10%	(Instructor & advisor)
	Team poster (due May 1)	= 100	10%	(Instructor & advisor)
	Assignment: Ethics (mandatory)	= 50	5%	(Instructor)
	Peer evaluations (mandatory)	= 50	5%	(Instructor)
	Lab cleanliness & safety	= 50	5%	(Committee)
	*Participation in recruiting events and SAE competition			
	Late work will be penalized 10% per day late.	(Total = 1000 pts)		

Figure 3 – Grading Scheme for Engineering Projects 2 prior to 2015-2016.

Observed Weaknesses in Curriculum

Through competition performance and interviews with students, several weaknesses with the course sequence were identified. First, competition performance for Lawrence Tech teams has been poor, with the exception of SAE Aero Design 2009-2012 and Formula Hybrid 2013-2014. These results are tabulated in Table 4. In several cases, such as Formula SAE 2015 and Formula Hybrid 2015, teams travelled to competition but were unable to pass technical inspection. SAE Aero Design results are based on advisor memory, as the competition does not release full results.

Table 4 – Lawrence Technological University SAE Competition Results.

Year	Baja SAE	Formula Hybrid	Formula SAE	SAE Aero Design	SAE Supermileage
2015	55/89	8/13	-	?	13/23
2014	33/91	2/11	101/107	?	-
2013	41/87	2/12	74/104	?	-
2012	83/102	13/20	85/105	10/45	-
2011	67/87	12/19	82/98	9/45	-
2010	58/85	3/5	75/102	8/45	-
2009	27/100	-	52/91	8/45	-

Student team leaders provided feedback in the Spring 2014 and Spring 2015 semesters. The 2014 Formula Hybrid team captain noted that little design work was being done, teams instead were focused on fabrication. In particular, Formula Hybrid had not completed any fluid or suspension calculations. Other students commented that classroom grades were not aligned with the competition vehicle and that they wanted their grades to reflect engineering work and not paperwork. This sentiment was echoed by faculty advisors who felt that the progress report deliverables were largely busywork and did not reflect actual design or fabrication work. Top requests from students were:

- Increase individual accountability
- Focus on engineering over paperwork
- Add a design and fabrication task to Introduction to Engineering Projects
- Replace progress reports with technical reports
- Use scheduled classroom time effectively
- Provide students with basic timeline

Faculty advisors interpreted student responses to mean that underutilization of in-class time left students feeling that classroom academic requirements were disconnected from CDS competition requirements. This was exacerbated by the use of a course instructor and an advisor for each team. Faculty advisors did not participate in classroom activities, except for scoring of presentations, and the course instructor did not participate in team design and fabrication activities.

The grading system for the three courses assigned a large proportion of available points to progress reports (20%) and deliverables associated with program accreditation (10%). Further, common departmental rubrics assigned only 60% of report and presentation credit to technical dimensions. This led students to feel that grades did not reflect their progress on the project. Submission of all assignments was often sufficient for students to receive a passing grade, regardless of the actual design or fabrication work completed. At times, this led to poor team dynamics as students who focused their time on actual vehicle design suffered lower scores on deliverables (written reports, seminar essay, etc.) and earned lower overall grades.

Finally, students were given complete autonomy on development of the project timeline which resulted in vehicles being completed only days before competition, if at all. This tied back to the exhibited poor competition placement.

Proposed Changes to Three Semester Sequence

Based on the identified curricular weaknesses, several modifications were made to the structure of the three semester capstone design sequence. These were:

- Requirements for competition attendance
- Revised syllabus to include scheduled classroom activities
- Team-teaching to include faculty advisors in the classroom
- Formalized process of assigning students to project teams
- Inclusion of a short design project in Introduction to Engineering Projects
- Replacement of individual progress reports with team technical reports
- Replacement of “participation and execution” with milestone-based scoring

The Lawrence Tech College of Engineering administration made the decision that, in the future, vehicles which were not operational, pre-tested, and could not pass an internal technical inspection prior to competition were not to be sent to their respective competitions. This requirement provided a clear guideline for students and established competition travel as a reward instead of an expectation.

The largest changes made were philosophical shifts. As explained above, previous efforts assumed that all project instruction was done informally by advisors and that classroom sessions were for administrative usage. Starting in Fall 2015, the department approved a plan to use classroom sessions for a mix of instruction, project work, and reporting of results by all teams. To further connect the classroom sessions with the projects, all faculty advisors agreed to participate in classroom sessions. Practically, this has implications for teaching load and may not be feasible for all readers. At Lawrence Tech, the effort was supported by the Dean of Engineering and the Provost.

With the decision made to use all classroom sessions for activities, the question was what to include. Starting in Fall 2015, a one-off implementation was tested in Engineering Projects 1. Topics were selected based on faculty advisor experience of past student struggles. Course content from Fall 2015 is shown in Table 5. As the material from Engineering Projects 1 (Fall 2015) included some backfill – the 2015-2016 teams accommodated the changes in the middle of their design sequence – a portion of this material was shifted to Introduction to Engineering Projects for Spring 2016 (the 1st course that the 2016-2017 teams take in their design sequence), as shown in Table 6. With student design completed in Engineering Projects 1, it was decided to use Engineering Projects 2 primarily for sharing progress between teams and lab work time, as shown in Table 7.

The most important classroom session of Engineering Projects 2 was session 13. The Blue Devil Motorsports Unveiling is an annual event at Lawrence Tech wherein the SAE CDS teams show their completed vehicles in an event open to the university and sponsors. In years past, vehicles were often unfinished and untested at the Unveiling. To address the College of Engineering administration requirement that only competition-ready vehicles travel to competition, the Unveiling date was selected as the deadline for vehicles to be demonstrated to be competition-ready. Engineering Projects 2 session 13 marks the decision point for teams to be allowed to attend competition.

The new project teams (2016-2017) were formed in Introduction to Engineering Projects (Spring 2016). In the first classroom session, students were introduced to the SAE teams through short presentations by each team. Where possible, captains of each SAE team presented their project. Where students were not available, the SAE team was presented by a faculty advisor. In the second classroom session, students were taken on a tour of the SAE team workspaces and given time to interact with current SAE team members. Each student was asked to complete a form stating preferred SAE projects. This process was formalized to reduce switching of students between projects. While not a large problem in the past, students switching project teams after 1 or 2 semesters caused disruption and shifted student workloads. The student preference form used is included in the Appendix A. Student teams were assigned, following preferences as much as possible, during session 4.

Table 5 – Engineering Projects 1 course content for Fall 2015

Session	Topic	Instructor(s)
1	Introduction, Safety and Security	F / Y
2	Skills Inventory, Mission/Vision	F / M
3	Team Organization	M
4	Creative Problem Solving	G
5	Design Specifications	L / Y
6	Change Control	F
7	Peer Evaluation	F
8	Budget and Purchasing	A
9	Bill of Materials	M
10	Communication Skills	G
11	Initial Design Review	All Advisors
12	Design Assessment: Rules	L
13	Design Assessment: Performance	A
14	Value Proposition	M
15	Design Review (Oral Presentation)	All Advisors

Table 6 – Introduction to Engineering Projects course content for Spring 2016

Session	Topic	Instructor(s)
1	SAE Competition Overview	All Advisors
2	Lab Tours	All Teams
3	Skills Inventory, Engineering Design	G / F
4	Team Formation	F
5	Project Intro, Team Organization	M
6	Software Tools	F
7	Time Management	L
8	Budget and Funding	A
9	Design Specifications	L
10	Design Concepts	Y
11	Design Assessment	Y
12	Design Fabrication & Validation	A
13	Communication Skills	G
14	Areas of Focus, Research	M
15	Design Review (Oral Presentation)	All Advisors

Table 7 – Engineering Projects 2 course content for Spring 2016

Session	Topic	Instructor(s)
1	Status Update	F
2	BoM Update	Y
3	Fabrication Tasks	F
4	Design Changes	M
5	Hardware Show and Tell	G
6	Fabricated Show and Tell	L
7	Lab Work Time with Show and Tell	G
8	Checkpoint	A
9	Lab Work Time with Show and Tell	M
10	Design Assessment: Rules	L
11	Design Assessment: Performance	A
12	Lab Work Time with Show and Tell	Y
13	BDM Unveiling, Go/No-Go	All Advisors
14	Lab Work Time with Show and Tell	F
15	Design Review (Oral Presentation)	All Advisors

A short design project was included in Introduction to Engineering Projects as a "warm-up" exercise. This may be considered a "designette", though our implementation is more similar to Cooper *et al.*[7] than to Wood *et al.*[8]. The designette was introduced in session 5. For the Baja SAE, Formula Hybrid, Formula SAE, and SAE Supermileage teams, the designette was to design, fabricate, and validate a device to aid transportation of the vehicle while at competition. For the SAE Aero Design team, the designette was to design, fabricate, and validate a device to aid construction testing of vehicle components. The selection of designette focus was made to force interaction between juniors in Introduction to Engineering Projects and seniors in Engineering Projects 2. In particular, seniors act as the customer for juniors. This modification alone warrants additional future study.

In assessment of student work during Engineering Projects 1 and 2, individual progress reports were replaced by team technical reports. Progress reports were typically one to two pages in length and itemized what individual students worked on for the time period, design accomplishments, progress, upcoming tasks, budget and timeline changes, and hours worked. A departmental rubric was used to assess the progress report. Many students felt that the progress reports were extra busywork and did not document their actual design or fabrication work. An example of a progress report template was shown in Appendix B. By contrast, technical reports required students to demonstrate the technical details of design and project management. For example, Engineering Projects 1 technical report 2 (template shown in Appendix C) covered design assessment and required teams to detail their vehicle component research, safety research, plan for component re-use, purchase, redesign, or new design, and project management updates. Even though it seemed more work compared to the previous progress reports, the students were gradually building their SAE design reports along the way. In previous years, students would rush to finish these before the competition deadlines.

Finally, for Engineering Projects 1 and 2, the "participation and execution" portion of the grading system was replaced by milestone-based scoring. Milestones were necessarily team-specific.

Likewise, the requirements for each milestone were left to the advisor. Some teams used mostly deliverable-based milestones while other teams leaned more to action-oriented milestones. Even with disparities between teams, these milestones were far less subjective than previous semesters.

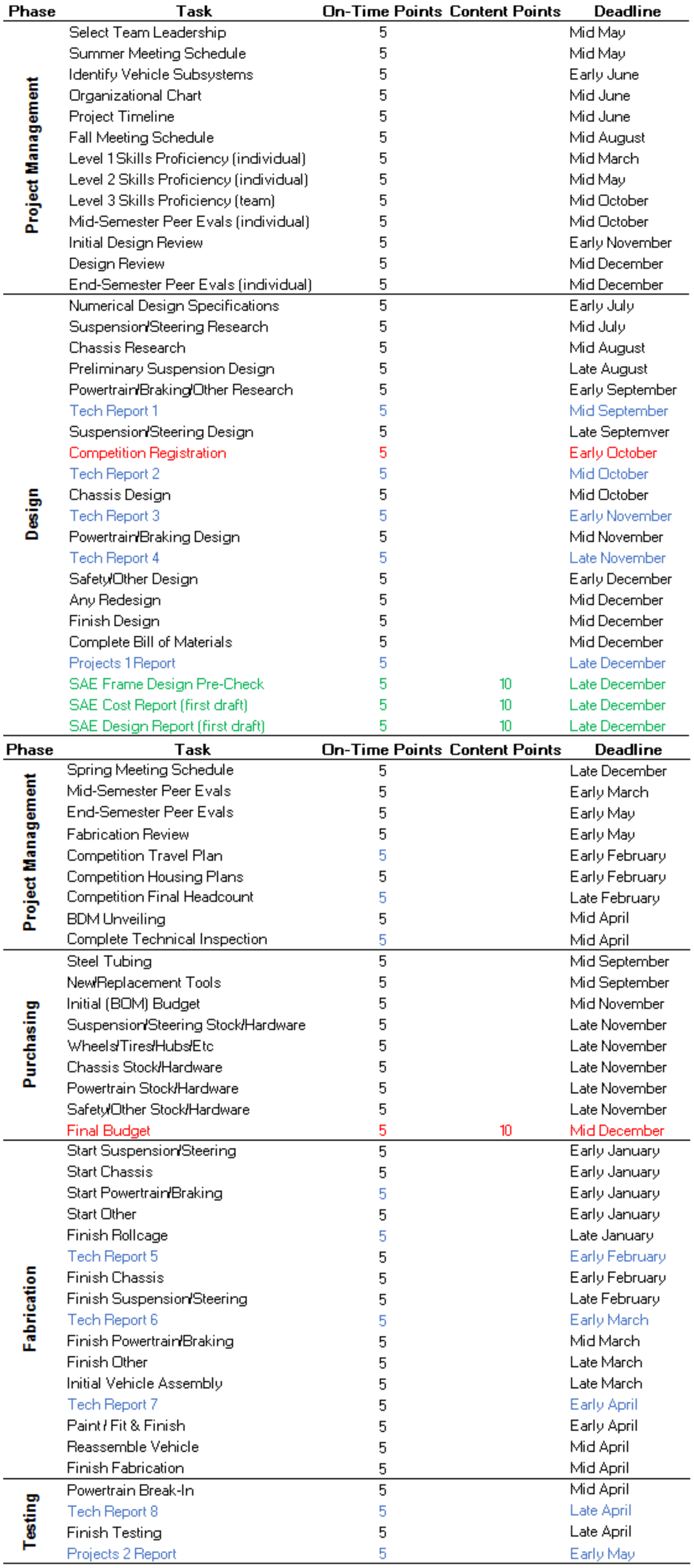
As an example, the Baja SAE team was provided by the faculty advisor with a set of milestones similar to that shown in Figure 4. All milestones were equally weighted, divided into categories, and assigned a rough deadline (e.g. late September) based on previous teams. Students worked from their schedules to set dates for each milestone as well as reorder and modify milestones as desired. Students were responsible for tracking the awarded points. The resulting Engineering Projects 1 milestones with student-selected deadlines are shown in Figure 5. Anecdotally, this process of selecting deadlines and tracking progress changed the milestones from an advisor-dictated schedule into a student-driven timeline. While the final design milestones were missed, work to that point was significantly better in timeliness and quality than recent teams, in the opinion of the faculty advisor.

Assessment of Course Modifications

Assessment of the effectiveness of the implemented course modifications comes in three forms: anecdotal observations by faculty advisors and students, indirect assessment of students using surveys at the completion of each semester, and direct assessment of student work samples by faculty advisors.

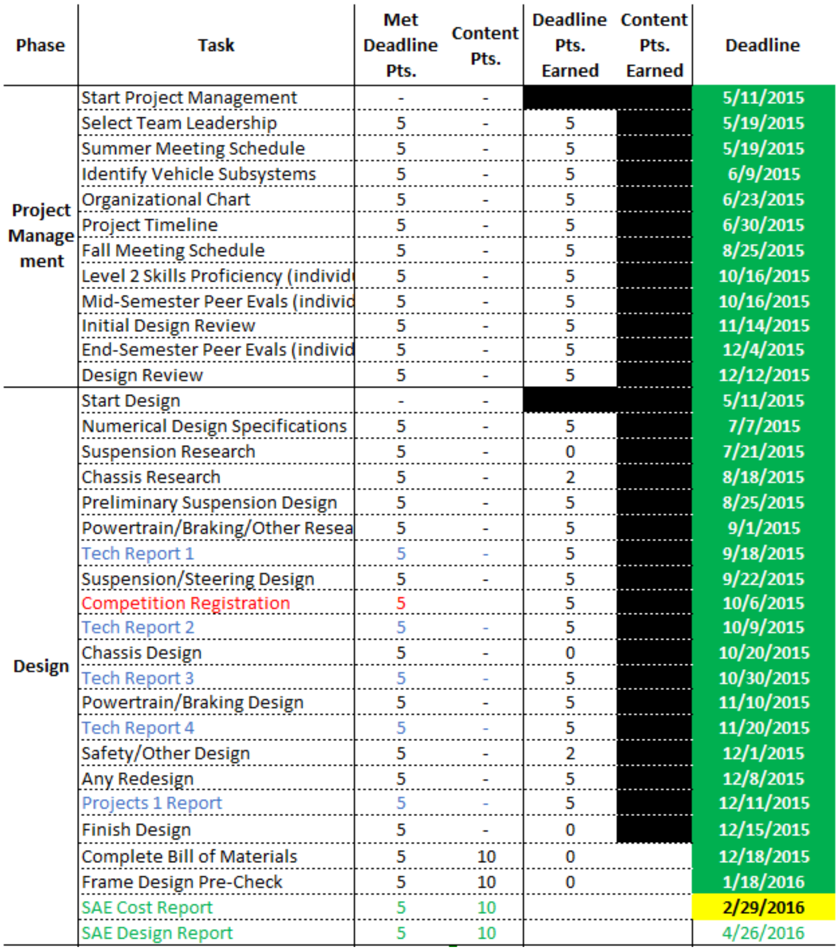
First, faculty advisors observed substantial improvement in student teams in the areas of project management, design quality and timing, and class camaraderie. Each team was responsible for an organization chart, often based on vehicle subsystems, as shown in Figure 6. Because they were developed by the students as a requirement of the course, these organization charts served as an official document and were frequently referenced to identify responsibility for tasks. Some student teams used their provided milestones to develop effective Gantt charts, such as the one shown in Table 8. Anecdotally, past student design projects without guidance for effective time management might create a Gantt chart after the fact, rather than as a project management tool. Use of a three semester design sequence allowed these project management aspects to be introduced during Introduction to Engineering Projects, in the context of the designette, then applied to the SAE CDS project during the Summer.

Second, faculty advisors observed that students completed design and fabrication tasks more quickly than in previous years. For example, the 2015 Baja SAE team did not finish front knuckle design until February 27th or start knuckle fabrication until March 27th but the 2016 Baja SAE team finalized all design on February 1st and started knuckle fabrication immediately. Also from the Baja SAE team, the first draft of the 2015 SAE Design Report was completed March 22nd while the first draft of the 2016 SAE Design Report was completed January 6th. This improvement appeared to be due to two changes: the guided development of a realistic, student-owned timeline and the direct connection between step-by-step progress and student grades.



Phase	Task	On-Time Points	Content Points	Deadline
Project Management	Select Team Leadership	5		Mid May
	Summer Meeting Schedule	5		Mid May
	Identify Vehicle Subsystems	5		Early June
	Organizational Chart	5		Mid June
	Project Timeline	5		Mid June
	Fall Meeting Schedule	5		Mid August
	Level 1 Skills Proficiency (individual)	5		Mid March
	Level 2 Skills Proficiency (individual)	5		Mid May
	Level 3 Skills Proficiency (team)	5		Mid October
	Mid-Semester Peer Evals (individual)	5		Mid October
	Initial Design Review	5		Early November
	Design Review	5		Mid December
	End-Semester Peer Evals (individual)	5		Mid December
Design	Numerical Design Specifications	5		Early July
	Suspension/Steering Research	5		Mid July
	Chassis Research	5		Mid August
	Preliminary Suspension Design	5		Late August
	Powertrain/Braking/Other Research	5		Early September
	Tech Report 1	5		Mid September
	Suspension/Steering Design	5		Late Septemver
	Competition Registration	5		Early October
	Tech Report 2	5		Mid October
	Chassis Design	5		Mid October
	Tech Report 3	5		Early November
	Powertrain/Braking Design	5		Mid November
	Tech Report 4	5		Late November
	Safety/Other Design	5		Early December
	Any Redesign	5		Mid December
	Finish Design	5		Mid December
	Complete Bill of Materials	5		Mid December
	Projects 1 Report	5		Late December
	SAE Frame Design Pre-Check	5	10	Late December
	SAE Cost Report (first draft)	5	10	Late December
	SAE Design Report (first draft)	5	10	Late December
Project Management	Spring Meeting Schedule	5		Late December
	Mid-Semester Peer Evals	5		Early March
	End-Semester Peer Evals	5		Early May
	Fabrication Review	5		Early May
	Competition Travel Plan	5		Early February
	Competition Housing Plans	5		Early February
	Competition Final Headcount	5		Late February
	BDM Unveiling	5		Mid April
	Complete Technical Inspection	5		Mid April
Purchasing	Steel Tubing	5		Mid September
	New/Replacement Tools	5		Mid September
	Initial (BOM) Budget	5		Mid November
	Suspension/Steering Stock/Hardware	5		Late November
	Wheels/Tires/Hubs/Etc	5		Late November
	Chassis Stock/Hardware	5		Late November
	Powertrain Stock/Hardware	5		Late November
	Safety/Other Stock/Hardware	5		Late November
	Final Budget	5	10	Mid December
Fabrication	Start Suspension/Steering	5		Early January
	Start Chassis	5		Early January
	Start Powertrain/Braking	5		Early January
	Start Other	5		Early January
	Finish Rollcage	5		Late January
	Tech Report 5	5		Early February
	Finish Chassis	5		Early February
	Finish Suspension/Steering	5		Late February
	Tech Report 6	5		Early March
	Finish Powertrain/Braking	5		Mid March
	Finish Other	5		Late March
	Initial Vehicle Assembly	5		Late March
	Tech Report 7	5		Early April
	Paint / Fit & Finish	5		Early April
	Reassemble Vehicle	5		Mid April
	Finish Fabrication	5		Mid April
Testing	Powertrain Break-In	5		Mid April
	Tech Report 8	5		Late April
	Finish Testing	5		Late April
	Projects 2 Report	5		Early May

Figure 4 – Sample milestones, taken from Lawrence Tech Baja SAE team.



Phase	Task	Met Deadline Pts.	Content Pts.	Deadline Pts. Earned	Content Pts. Earned	Deadline
Project Management	Start Project Management	-	-			5/11/2015
	Select Team Leadership	5	-	5		5/19/2015
	Summer Meeting Schedule	5	-	5		5/19/2015
	Identify Vehicle Subsystems	5	-	5		6/9/2015
	Organizational Chart	5	-	5		6/23/2015
	Project Timeline	5	-	5		6/30/2015
	Fall Meeting Schedule	5	-	5		8/25/2015
	Level 2 Skills Proficiency (individ	5	-	5		10/16/2015
	Mid-Semester Peer Evals (indivic	5	-	5		10/16/2015
	Initial Design Review	5	-	5		11/14/2015
	End-Semester Peer Evals (individ	5	-	5		12/4/2015
	Design Review	5	-	5		12/12/2015
Design	Start Design	-	-			5/11/2015
	Numerical Design Specifications	5	-	5		7/7/2015
	Suspension Research	5	-	0		7/21/2015
	Chassis Research	5	-	2		8/18/2015
	Preliminary Suspension Design	5	-	5		8/25/2015
	Powertrain/Braking/Other Resea	5	-	5		9/1/2015
	Tech Report 1	5	-	5		9/18/2015
	Suspension/Steering Design	5	-	5		9/22/2015
	Competition Registration	5		5		10/6/2015
	Tech Report 2	5	-	5		10/9/2015
	Chassis Design	5	-	0		10/20/2015
	Tech Report 3	5	-	5		10/30/2015
	Powertrain/Braking Design	5	-	5		11/10/2015
	Tech Report 4	5	-	5		11/20/2015
	Safety/Other Design	5	-	2		12/1/2015
	Any Redesign	5	-	5		12/8/2015
	Projects 1 Report	5	-	5		12/11/2015
	Finish Design	5	-	0		12/15/2015
	Complete Bill of Materials	5	10	0		12/18/2015
	Frame Design Pre-Check	5	10	0		1/18/2016
	SAE Cost Report	5	10			2/29/2016
	SAE Design Report	5	10			4/26/2016

Figure 5 – Student-tracked milestones for Engineering Projects 1, taken from Lawrence Tech Baja SAE team.

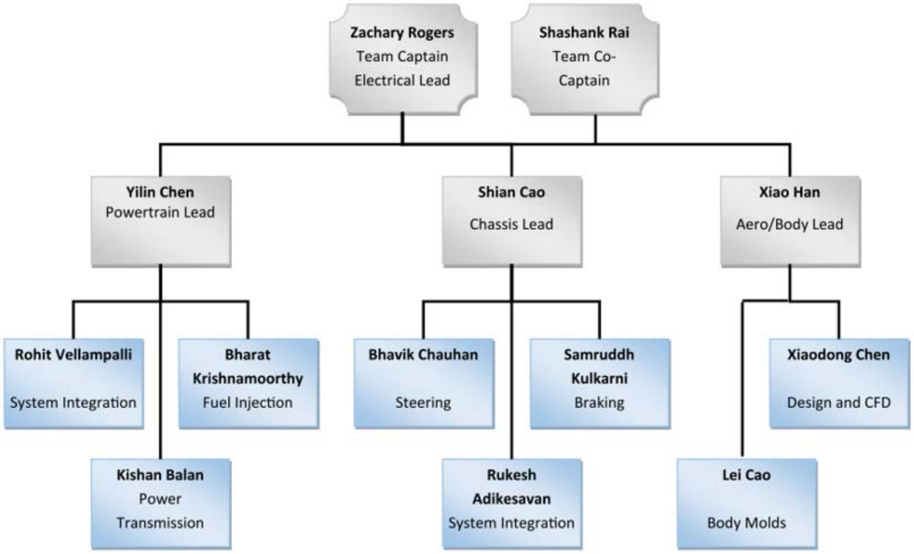
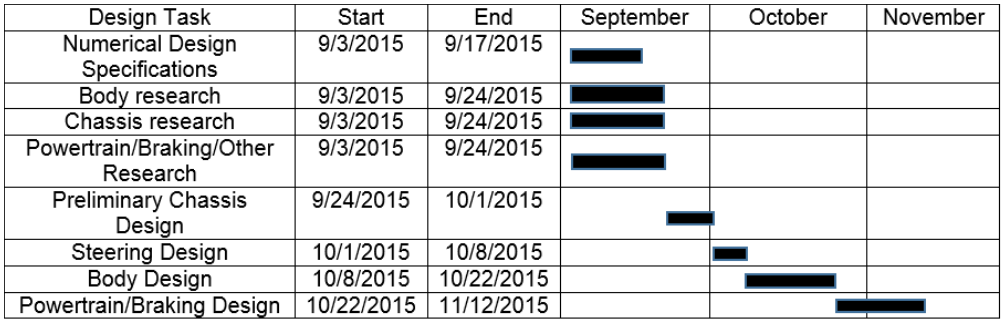


Figure 6 - Team organization, from Lawrence Tech SAE Supermileage team.

Table 8 - Gantt table of design task timeline, from Lawrence Tech SAE Supermileage team.



Design Task	Start	End	September	October	November
Numerical Design Specifications	9/3/2015	9/17/2015	■		
Body research	9/3/2015	9/24/2015	■		
Chassis research	9/3/2015	9/24/2015	■		
Powertrain/Braking/Other Research	9/3/2015	9/24/2015	■		
Preliminary Chassis Design	9/24/2015	10/1/2015	■		
Steering Design	10/1/2015	10/8/2015		■	
Body Design	10/8/2015	10/22/2015		■	
Powertrain/Braking Design	10/22/2015	11/12/2015		■	■

Finally, faculty advisors observed that routine sharing of organization, design, and fabrication progress between teams enabled cross-pollination and improved camaraderie among students. As an example, student teams shared their methods for tracking a complete bill of materials. Each student team had a different design, with different dimensions, and different levels of detail. Each team was able to adopt useful improvements that they saw from other teams. During Spring 2016, the Formula SAE team was the first team to demonstrate a rolling chassis. This announcement prompted both spontaneous applause and the SAE Aero Design team's overnight completion of an airplane skeleton.

Initial indirect assessment of student learning was conducted by surveys at the conclusion of the Spring 2016 semester. Further assessment will be completed at the conclusion of each of the three semesters during the design sequence. Students were asked four general questions about the project and whether "This project improved my technical skills in:", and answers are provided in 5 scales:

1. Strongly disagree
2. Disagree
3. No opinion
4. Agree
5. Strongly agree

Survey questions

1. I consider the results of my project successful.
2. I found my work on the project to be satisfying.
3. The real-world application of the project motivated me to do my best work.
4. The open-ended nature of the project motivated me to do my best work.

This project improved my technical skills in:

5. Project organization.
6. Time management.
7. Project management.
8. Design of mechanical components.
9. Analysis of mechanical components.
10. Fabrication of mechanical components.
11. Design of thermo-fluid components.
12. Analysis of thermo-fluid components.
13. Fabrication of thermo-fluid components.
14. Designing a real-world fluid system.
15. Reporting the solution to a customer.

During the first round of data collection, students were surveyed at the conclusion of the Spring 2016 semester. Survey results are shown in Table 9. Two groups of students were included: those completing Introduction to Engineering Projects and those completing Engineering Projects 2. Response rate for Introduction to Engineering Projects was 100% (44/44) because the surveys were submitted during class. Response rate for Engineering Projects 2 was significantly lower at 82% (28/34) due to the Formula Hybrid team traveling during the survey period. Several Formula Hybrid members submitted surveys, but the team is underrepresented in the presented results for Engineering Projects 2.

Table 9 - Survey results assessing technical skills during Spring 2016.

Question #	**Intro Engr Proj (N = 44)**		**Engr Proj 2 (N = 28)**	
	Mean	Standard Deviation	Mean	Standard Deviation
1	4.25	0.86	3.96	0.82
2	3.91	1.04	4.21	0.86
3	3.95	0.87	3.96	1.05
4	3.84	0.91	3.85	1.04
5	3.95	0.59	4.25	0.51
6	3.91	0.82	3.89	1.08
7	4.02	0.62	4.21	0.67
8	4.05	0.94	4.36	0.67
9	4.07	0.75	4.21	0.86
10	4.29	0.90	4.50	0.63
11	2.77	1.15	3.57	1.15
12	2.72	1.20	3.50	1.15
13	2.84	1.25	3.64	1.08
14	2.74	1.24	3.50	1.09
15	3.93	0.77	4.04	0.68

From the survey results in Table 9, Introduction to Engineering Projects students agreed that the project improved their project management skills (average feedback of 4.02 to questions 7) while Engineering Projects 2 students agreed that the project improved their project organization (average feedback of 4.25 to question 5) and project management skills (average feedback of 4.21 to questions 7).

While students in both courses saw improvement in their design, analysis, and fabrication skills for mechanical components (questions 8, 9, and 10), results were mixed on design, analysis, and fabrication skills for thermo-fluid systems (questions 11, 12, and 13). This was expected due to the choice of task for the designette and the SAE CDS events. While the SAE CDS events feature thermo-fluid components (e.g. SAE Aero Design wing, Formula SAE intake), many students were focused on other aspects (e.g. Baja SAE suspension, Formula Hybrid chassis).

The free response section of the survey asked students:

1. What did you like (or appreciate) about the project?

2. What should be changed?
3. Additional comments/observations

Students enrolled in Introduction to Engineering Projects generally appreciated the project but disliked the additional deliverables, such as CAD training using Siemens NX software:

- "Gets you to work on a physical project for the 2016 team."
- "It was very open ended and allowed us to think creatively."
- "I liked how our project had real values to real 'customers'. This made me take my work more seriously than some theoretical projects given in other courses."
- "The project required a bit of critical thinking but was very rewarding in the end."
- "NX training unrealistic with making time to work on 2016 team…"
- "Too much things to be done and not enough time to really take in and learn what you are doing."
- "For a one-credit course, the workload for this course … was absolutely ludicrous."
- "No more NX training."
- "The NX training is beneficial to learn and prepare yourselves for design work, but it is unreasonable. It was impossible to complete on time with everything that is going on."
- "A meaningful learning experience and gain a lot."

Students enrolled in Engineering Projects 2 similarly appreciated the project but did not enjoy deliverables or the frantic pace at the end of the semester.

- "I liked the openness of the project."
- "I liked working with other students to design, build, and test a Formula SAE vehicle."
- "Project [taught] me how to communicate with other team members."
- "All these final reports and presentations are a waste of time; we gots a car to build."
- "Logbooks are archaic and unnecessary."
- "I haven't slept in days."

Direct assessment of student work takes three forms: assessment of student design reports using a rubric, assessment of student design presentations using a rubric, and assessment of the resulting vehicles for competition attendance. First, student design reports were assessed using a department rubric. Reports were evaluated on a team basis by the corresponding faculty advisor and rubrics are shown in Appendix E. Results of the assessment are shown in Table 10. At this time, Spring 2016 reports have not yet been evaluated.

Table 10 – Direct assessment of written design reports using a rubric.

		Intro Engr Proj	**Engr Proj 1**	**Engr Proj 2**
Baja SAE	2014 – 2015	60.5%	80.0%	75.0%
	2015 – 2016	74.0%	95.0%	N/A
Formula Hybrid	2014 – 2015	95.0%	95.0%	84.0%
	2015 – 2016	95.0%	96.0%	N/A
Formula SAE	2014 – 2015	65.0%	57.0%	65.0%
	2015 – 2016	93.5%	91.0%	N/A
SAE Aero Design	2014 – 2015	90.0%	90.0%	95.5%
	2015 – 2016	87.5%	90.05	N/A
SAE Supermileage	2014 – 2015	-	-	-
	2015 – 2016	91.5	91.0	N/A

Next, oral presentations were assessed with a rubric, shown in Appendix F. Students were evaluated individually by multiple faculty advisors (Introduction to Engineering Projects) or by a combination of faculty advisor and IAB members (Engineering Projects 2) with results of the assessment shown in Table 11.

Table 11 – Direct assessment of oral presentations using a rubric.

	Intro Engr Proj		**Engr Proj 1**		**Engr Proj 2**	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
2014 – 2015	93.8%	5.6	84.0%	12.8	87.4%	6.0
2015 – 2016	85.0%	12.4	86.4%	8.2	86.0%	9.8

It was expected that students would show an increase in both written report and oral presentation scores across the duration of the three semester course sequence. However, this trend was not seen in the data. As the initial assessment data represents both semesters before the current redesign (2014 – 2015) and after the current redesign (2015 – 2016), changes in course content and expectations may play a role in the data.

The final form of direct assessment reflected the College of Engineering requirements that vehicles be operational, pre-tested, and capable of passing technical inspection prior to competition in order to be allowed to compete. Following the Blue Devil Motorsports Unveiling event, teams were judged by the faculty advisors on the basis of meeting these requirements. A formal rubric was not used, instead all requirements were required to be met in order to be cleared for competition. Results, as presented to the students, are shown in Table 12.

Table 12 – Lawrence Tech SAE CDS teams approval for attending Spring 2016 competitions.

Team	**Go/No-Go**
Baja SAE	Conditional
Formula Hybrid	Conditional
Formula SAE	Go
SAE Aero Design	Go
SAE Supermileage	Go

Two teams were granted conditional approval for competition travel: Baja SAE and Formula Hybrid. The Baja SAE team was registered for competition in June. At the time of the go/no-go decision, the Baja SAE team had almost two months to prepare and was missing only gears for the gearbox in order to demonstrate operation. The team successfully drove their vehicle during a “test and tune” event two weeks later. The Formula Hybrid team successfully drove their vehicle using the IC engine but could not test the hybrid mode due to an error in battery management software donated by a sponsor. This issue was resolved prior to competition. In terms of the final direct assessment, all teams received passing marks.

Conclusions

Weaknesses were identified in the three-semester capstone design sequence at Lawrence Tech and the authors proposed modifications to the sequence to better serve students for SAE CDS projects. The modifications include a revised syllabus to utilize in-class time, use of team-teaching to include faculty advisors in the classroom, revised deliverables based on student work rather than presentation, and milestone-based scoring for the students' project execution portion of grading system. Initial implementation indicated that all teams were performing much better in both project progress and timeline management. Additional data collection is needed in future semesters.

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5. Todd, R. H., et al. (1995) "A survey of capstone engineering courses in North America." *Journal of Engineering Education* vol. 84 165-174.
6. Mikesell, D. and Moyer, A. (2011) "From Crippled to Competitive: One School's Transition to a Volunteer Team in the Baja CDS," SAE Technical Paper 2011-01-1111.
7. Cooper, C. A., Anderson, M. L., Bruce, C., Dorman, S. G., Jensen, D. D., Otto, K., Wood, K. L. (2015) "Designettes in Capstone: Initial Design Experiences to Enhance Students' Implementation of Design Methodology," *Proceedings of the 2015 ASEE Annual Conference*.
8. Wood, K. K., Mohan, R. E., Kajima, S., Dritsas, S., Frey, D. D., White, C. K., Jensen, D. D., Crawford, R. H., Moreno, D., Pey, K.-L. (2012) "A Symphony of Designettes: Exploring the Boundaries of Design Thinking in Engineering Education," *Proceedings of the 2012 ASEE Annual Conference*.

Appendix A – Declaration of SAE Team Preference

Declaration of SAE Team Preference

Name: ____

Email: ____

ID Number: ____

Please rank your top 3 preferences for SAE teams with 1 being the highest. In your rankings, please indicate if you have experience working with the team.

1. ____
2. ____
3. ____

While the EME 3011 Course Coordinator will make every effort to match you with your top choice, there is a chance that you will be chosen for a team of your 2nd or 3rd choice. You are expected to join the SAE team that is offered to you.

By signing this form you agree to the following:

- Your professional reputation and the school's reputation are affected by your performance on an SAE competition team. Dropping a competition team negatively affects the team and the school's reputation. Therefore, you are expected to carefully consider you choice and only select those teams you would accept.
- The provisions of the Student Handbook, Academic Honor Code, and team-specific rules apply to all facets of the design project. You are expected to act professionally and ethically at all times.
- Your team is expected to design, fabricate, and validate a competition-ready vehicle. Failure to meet the expectation will result in failure of EME 4212, EME 4222, or both.

Signature: ____

Date: ____________________

Appendix B – Sample Progress Report Format

XXXXXX University

XXXXXX Department of Mechanical Engineering

EME4212 Engineering Projects 1

Progress Report # 1

Date:

Name of Student: **Faculty Advisor:**	**Name of Project:** Sub-group:
1. What's the overall purpose of the project (or sub-group): *may stay the same throughout the semester.* (0)	
2. Summarize your own accomplishments since the last progress report. (15)	
3. What expenditures did you have since the last progress report? Were these within the budget? (10)	
4. What work do you expect to do during the next month? Are you on schedule? (10)	
5. Are there any issues, problems or budget concerns? What tasks are behind schedule? (10)	
6. How many hours have you worked on this project since the last report? (15) What is the average hours/week worked on this project?	

Writing, grammar, English, etc. (40 points)

Appendix C – Sample Technical Report Format

EME 4212 Engineering Projects 1
Fall 2015

Technical Report #2

Report Due Date: MM/DD/YYYY

Competition Team Name *(Formula Hybrid, Baja, etc)*

Sr. Projects Team members

Print team member #1 name's, sign here:

____

Print team member #1 name's, sign here:

____

Print team member #1 name's, sign here:

____

(etc.)

Honor Code Pledge

"I have neither given nor received unauthorized aid in completing this work, nor have I presented someone else's work as my own."

(Body of report in 12 point Times New Roman font, with 1 inch borders)

1. Name of competition *(in which your team is competing)*

2. Name of Vehicle *(some competitions request a vehicle name, list the name that your team has chosen for your vehicle).*

3. Technical Assessment stage:
    - 3.1. Design specifications from the competition rules
        - 3.1.1. General higher-level design specifications for the vehicle: *List these, and note these should not be detailed*.
        - 3.1.2. Specific design specifications that your team has identified that are critical and must be addressed for your team to be a success: *These are either from the rules or from what your team has learned from competition history.*
    - 3.2. Component research: *List each major vehicle component, cite and reference (with a reference number in the reference section of this report) the research your team has done for each of these components. In a short paragraph describe the supporting research undertaken for each component, including how and why it is relevant to the component. This research could be SAE technical papers or other technical papers, articles from racing magazines, and/or conversations with technical experts or suppliers, or other appropriate references. Note that referencing other competition team's website is not considered and adequate reference. All vehicle components or sub-components proposed for your vehicle must have research justification.*
        - 3.2.1. Re-use/purchase/redesign/new design: *(note that there will be several of these)*
            - 3.2.1.1. *List all major components that will be re-used from previous vehicles with supporting justification*
            - 3.2.1.2. *List all major purchased components with costs and supporting justification*
            - 3.2.1.3. *List all major components which will be redesigned or modified and provide preliminary concepts for each of these (sketches and/or proposed verbal descriptions are acceptable)*
            - 3.2.1.4. *List all new-design components and provide preliminary concepts for each of these (sketches or verbal descriptions are acceptable)*
    - 3.3. Safety research
        - 3.3.1. Identify your team's safety officer
        - 3.3.2. Review the Safety Rules for the competition and identify critical safety requirements for your vehicle: *(List in general how you propose to have your vehicle comply with these rules. You are <u>not</u> being asked for specific designs for safety compliance at this time, but rather how your vehicle needs to comply.)*

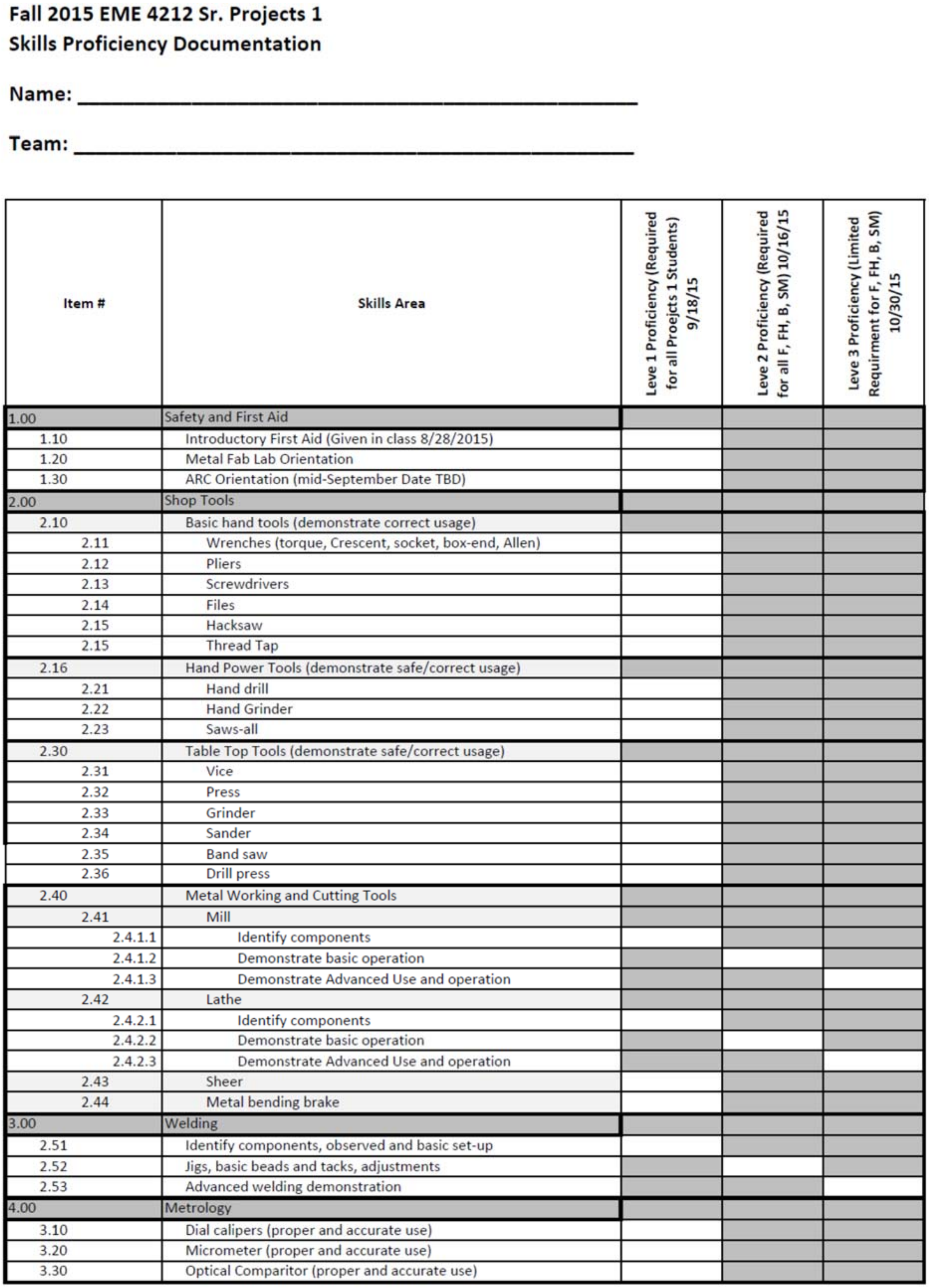
4. Project management update:

- 4.1. Schedule
  - 4.1.1. Milestones since Tech Report 1
    - *4.1.1.1.* Status *(discuss)*
    - 4.1.1.2. Schedule concerns *(address each)*
    - 4.1.1.3. Required schedule modifications *(list with an explanation)*
  - 4.1.2. Milestones to be completed before Tech Report 3 is issued *(list)*
- 4.2. Budget – Review status *(funds needed, funds secured, proposed fund raising approach for team)*

5. Contributors to this report *(list which Sr. Projects 1 students contributed to each of the individual sections this report and what they contributed)*

6. References *(this must be a separate section included for all research done in part 3.1 above; each reference listed here must be numbered and cited by number in the text of the repor)*
   - 6.1. Each source must have a short literature review
     - 6.1.1. What did the source do? (major results – one or two sentences)
     - 6.1.2. How does this apply to your work? (relevance – one or two sentences)
     - 6.1.3. What did the source do well? (strengths – one or two sentences)
     - 6.1.4. What did the source not do well? (weaknesses/opportunities – one or two sentences)

Appendix D – Skills Proficiency Documentation



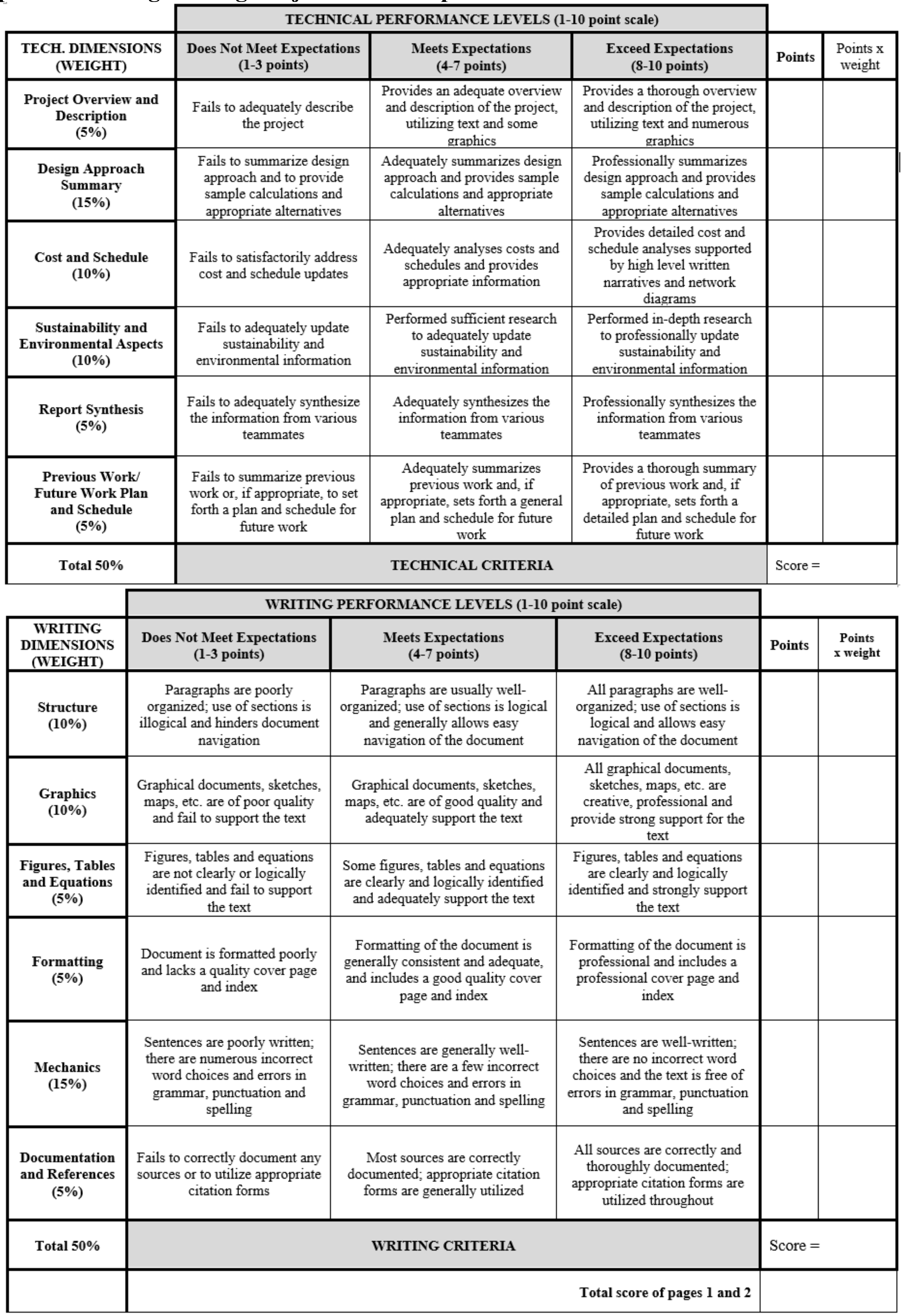
Fall 2015 EME 4212 Sr. Projects 1
Skills Proficiency Documentation

Name: ____

Team: ____

Item #	Skills Area	Leve 1 Proficiency (Required for all Proejcts 1 Students) 9/18/15	Leve 2 Proficiency (Required for all F, FH, B, SM) 10/16/15	Leve 3 Proficiency (Limited Requirment for F, FH, B, SM) 10/30/15
1.00	Safety and First Aid	▨	▨	▨
1.10	Introductory First Aid (Given in class 8/28/2015)		▨	▨
1.20	Metal Fab Lab Orientation		▨	▨
1.30	ARC Orientation (mid-September Date TBD)		▨	▨
2.00	Shop Tools	▨	▨	▨
2.10	Basic hand tools (demonstrate correct usage)	▨	▨	▨
2.11	Wrenches (torque, Crescent, socket, box-end, Allen)		▨	▨
2.12	Pliers		▨	▨
2.13	Screwdrivers		▨	▨
2.14	Files		▨	▨
2.15	Hacksaw		▨	▨
2.15	Thread Tap		▨	▨
2.16	Hand Power Tools (demonstrate safe/correct usage)	▨	▨	▨
2.21	Hand drill		▨	▨
2.22	Hand Grinder		▨	▨
2.23	Saws-all		▨	▨
2.30	Table Top Tools (demonstrate safe/correct usage)	▨	▨	▨
2.31	Vice		▨	▨
2.32	Press		▨	▨
2.33	Grinder		▨	▨
2.34	Sander		▨	▨
2.35	Band saw		▨	▨
2.36	Drill press		▨	▨
2.40	Metal Working and Cutting Tools	▨	▨	▨
2.41	Mill	▨	▨	▨
2.4.1.1	Identify components		▨	▨
2.4.1.2	Demonstrate basic operation	▨		▨
2.4.1.3	Demonstrate Advanced Use and operation	▨	▨	
2.42	Lathe	▨	▨	▨
2.4.2.1	Identify components		▨	▨
2.4.2.2	Demonstrate basic operation	▨		▨
2.4.2.3	Demonstrate Advanced Use and operation	▨	▨	
2.43	Sheer		▨	▨
2.44	Metal bending brake		▨	▨
3.00	Welding	▨	▨	▨
2.51	Identify components, observed and basic set-up		▨	▨
2.52	Jigs, basic beads and tacks, adjustments	▨		▨
2.53	Advanced welding demonstration	▨	▨	
4.00	Metrology	▨	▨	▨
3.10	Dial calipers (proper and accurate use)		▨	▨
3.20	Micrometer (proper and accurate use)		▨	▨
3.30	Optical Comparitor (proper and accurate use)		▨	▨

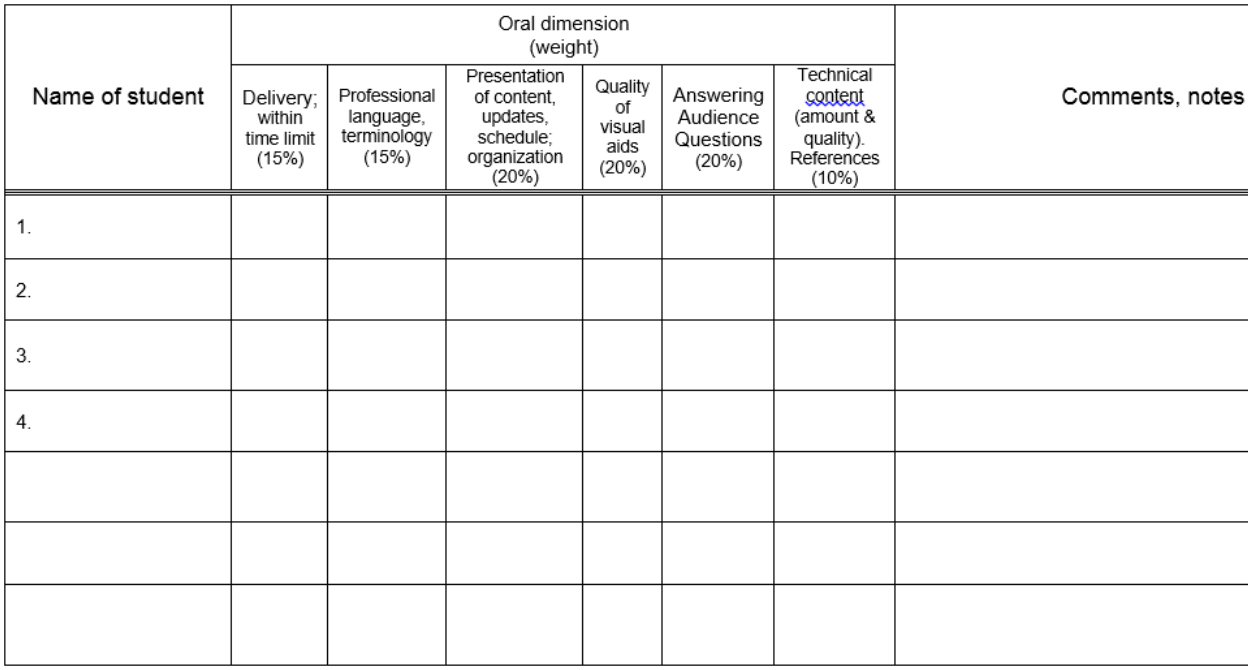
Appendix E – Engineering Projects 1 & 2 Report Rubric



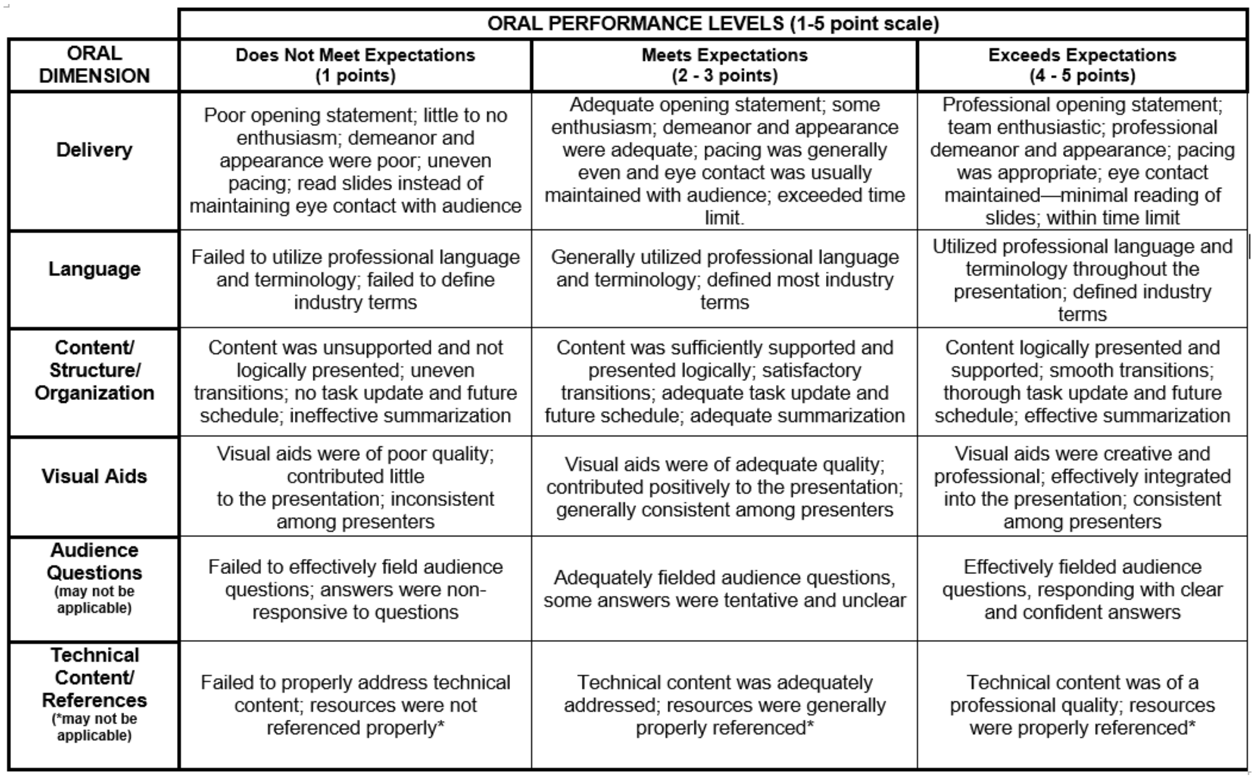
TECH. DIMENSIONS (WEIGHT)	TECHNICAL PERFORMANCE LEVELS (1-10 point scale) Does Not Meet Expectations (1-3 points)	Meets Expectations (4-7 points)	Exceed Expectations (8-10 points)	Points	Points x weight
Project Overview and Description (5%)	Fails to adequately describe the project	Provides an adequate overview and description of the project, utilizing text and some graphics	Provides a thorough overview and description of the project, utilizing text and numerous graphics		
Design Approach Summary (15%)	Fails to summarize design approach and to provide sample calculations and appropriate alternatives	Adequately summarizes design approach and provides sample calculations and appropriate alternatives	Professionally summarizes design approach and provides sample calculations and appropriate alternatives		
Cost and Schedule (10%)	Fails to satisfactorily address cost and schedule updates	Adequately analyses costs and schedules and provides appropriate information	Provides detailed cost and schedule analyses supported by high level written narratives and network diagrams		
Sustainability and Environmental Aspects (10%)	Fails to adequately update sustainability and environmental information	Performed sufficient research to adequately update sustainability and environmental information	Performed in-depth research to professionally update sustainability and environmental information		
Report Synthesis (5%)	Fails to adequately synthesize the information from various teammates	Adequately synthesizes the information from various teammates	Professionally synthesizes the information from various teammates		
Previous Work/ Future Work Plan and Schedule (5%)	Fails to summarize previous work or, if appropriate, to set forth a plan and schedule for future work	Adequately summarizes previous work and, if appropriate, sets forth a general plan and schedule for future work	Provides a thorough summary of previous work and, if appropriate, sets forth a detailed plan and schedule for future work		
Total 50%		**TECHNICAL CRITERIA**		Score =	

WRITING DIMENSIONS (WEIGHT)	WRITING PERFORMANCE LEVELS (1-10 point scale) Does Not Meet Expectations (1-3 points)	Meets Expectations (4-7 points)	Exceed Expectations (8-10 points)	Points	Points x weight
Structure (10%)	Paragraphs are poorly organized; use of sections is illogical and hinders document navigation	Paragraphs are usually well-organized; use of sections is logical and generally allows easy navigation of the document	All paragraphs are well-organized; use of sections is logical and allows easy navigation of the document		
Graphics (10%)	Graphical documents, sketches, maps, etc. are of poor quality and fail to support the text	Graphical documents, sketches, maps, etc. are of good quality and adequately support the text	All graphical documents, sketches, maps, etc. are creative, professional and provide strong support for the text		
Figures, Tables and Equations (5%)	Figures, tables and equations are not clearly or logically identified and fail to support the text	Some figures, tables and equations are clearly and logically identified and adequately support the text	Figures, tables and equations are clearly and logically identified and strongly support the text		
Formatting (5%)	Document is formatted poorly and lacks a quality cover page and index	Formatting of the document is generally consistent and adequate, and includes a good quality cover page and index	Formatting of the document is professional and includes a professional cover page and index		
Mechanics (15%)	Sentences are poorly written; there are numerous incorrect word choices and errors in grammar, punctuation and spelling	Sentences are generally well-written; there are a few incorrect word choices and errors in grammar, punctuation and spelling	Sentences are well-written; there are no incorrect word choices and the text is free of errors in grammar, punctuation and spelling		
Documentation and References (5%)	Fails to correctly document any sources or to utilize appropriate citation forms	Most sources are correctly documented; appropriate citation forms are generally utilized	All sources are correctly and thoroughly documented; appropriate citation forms are utilized throughout		
Total 50%		**WRITING CRITERIA**		Score =	
			Total score of pages 1 and 2		

Appendix F – Oral Presentation Rubric



Name of student	Oral dimension (weight)						Comments, notes
	Delivery; within time limit (15%)	Professional language, terminology (15%)	Presentation of content, updates, schedule; organization (20%)	Quality of visual aids (20%)	Answering Audience Questions (20%)	Technical content (amount & quality). References (10%)	
1.							
2.							
3.							
4.							



	ORAL PERFORMANCE LEVELS (1-5 point scale)		
ORAL DIMENSION	**Does Not Meet Expectations (1 points)**	**Meets Expectations (2 - 3 points)**	**Exceeds Expectations (4 - 5 points)**
Delivery	Poor opening statement; little to no enthusiasm; demeanor and appearance were poor; uneven pacing; read slides instead of maintaining eye contact with audience	Adequate opening statement; some enthusiasm; demeanor and appearance were adequate; pacing was generally even and eye contact was usually maintained with audience; exceeded time limit.	Professional opening statement; team enthusiastic; professional demeanor and appearance; pacing was appropriate; eye contact maintained—minimal reading of slides; within time limit
Language	Failed to utilize professional language and terminology; failed to define industry terms	Generally utilized professional language and terminology; defined most industry terms	Utilized professional language and terminology throughout the presentation; defined industry terms
Content/ Structure/ Organization	Content was unsupported and not logically presented; uneven transitions; no task update and future schedule; ineffective summarization	Content was sufficiently supported and presented logically; satisfactory transitions; adequate task update and future schedule; adequate summarization	Content logically presented and supported; smooth transitions; thorough task update and future schedule; effective summarization
Visual Aids	Visual aids were of poor quality; contributed little to the presentation; inconsistent among presenters	Visual aids were of adequate quality; contributed positively to the presentation; generally consistent among presenters	Visual aids were creative and professional; effectively integrated into the presentation; consistent among presenters
Audience Questions (may not be applicable)	Failed to effectively field audience questions; answers were non-responsive to questions	Adequately fielded audience questions, some answers were tentative and unclear	Effectively fielded audience questions, responding with clear and confident answers
Technical Content/ References (*may not be applicable)	Failed to properly address technical content; resources were not referenced properly*	Technical content was adequately addressed; resources were generally properly referenced*	Technical content was of a professional quality; resources were properly referenced*