Paper ID #37673

# MAPPING OF ABET REQUIREMENTS THROUGH SENIOR DESIGN PROJECTS


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# MAPPING OF ABET REQUIREMENTS THROUGH SENIOR DESIGN PROJECTS


## Abstract

ABET's most current set of required Outcomes is highly logical and comprehensive (Criterion: 3). In most cases, however, mapping all of these requirements in the earlier courses may pose considerable challenges to Engineering educators. The authors suggest that capstone projects may serve as highly viable candidates for alleviating the above concern. However, this should not be treated as an arbitrary process. It is necessary first to lay a solid foundation for the successful implementation of Senior Projects. The authors propose a promising and well-tested model for conducting Senior Design Projects. Details of the 33 timed steps of the proposed model are summarized in a single table. They share their tested recommendations for the formation of Senior Project Teams and how to increase their chances for optimal performance. They have identified and organized the broad resources that may become available for conducting assessments. They present how, through well-timed interventions, such resources may effectively map into select Outcomes. They share the method of assessment and mapping adopted in their program. To illustrate the potency of the proposed approach, the authors present a condensed summary and analysis of the data of one such survey. The results are based on data on Forty (40)+ distinct Senior Projects in the past three iterations. The analysis of the data reflects on the degree of success in effectiveness of this suggested mapping. Additional samples of surveys are included in the appendices.


## Introduction

Engineering education is constantly evolving to meet the changing needs of students. As one would expect, many of these changes are initiated and paced by the radical advances in technology. In addition, however, engineering education must also consider those subtle changes occurring in the social system, the changes in the needs and wants of the "end-user" (consumer), and the changing needs and desires of the engineering professionals. These variables place fundamental constraints on the continued development of the engineering education program, specifically on the engineering design element [1].

Primary expectations from a Senior Design Project is defined by ABET with an emphasis on product, process, and professionalism. In principle, the requirements for a senior design project should include the development of student creativity, use of open-ended problems, development, and use of design methodology, formulation of design problems, alternative solutions, and detailed system description. Constraints such as economic factors, safety, reliability, ethics, and social impact should also be included [2]. Goldberg [3] presents a strong argument that due to its culminating nature, the senior design project course is probably the most significant experience of the undergraduate engineering students.

The Vision 2030 [4] task force used the ASME Global Summit and NAE Grand Challenges as a starting point to further define the areas where mechanical engineers can provide leadership in developing innovative and sustainable solutions to these challenges. The areas are broadly organized into sustainable engineering, energy, and human health [4]. Regarding the integration of the "Professional Experience" into the "Design (and Innovation) process, the *2030 Vision* task force recommends:

> *To strengthen the 'professional experience' component of the students' skill set, a significant portion of the curriculum needs to be dedicated to such activities. In this case, the ME curriculum should contain a design/build spine in which there would be a semester long design course in each of the freshmen, sophomore, and junior years, and a two semester year long senior capstone design course. In this design/build sequence, important elements of professional practice such as problem solving, design, teamwork, and communication would be introduced, and then reinforced in subsequent courses in the spine. Professional skills such as problem solving, teamwork, leadership, entrepreneurship, innovation, and project management would be central features of the design spine. The 'problem solving' skills area also incorporates problem formulation and judgment. Rather than propose a course in 'leadership', or a course in 'innovation', we think that these skills should be learned in the context of a structured approach to problem solving - problem formulation, problem analysis, and solution. The 'Grand Challenges' can be incorporated as elements into the early design courses to help provide a context and engineering background for students as they take the science and mathematics analysis courses. This also aids in indicating to students the areas where mechanical engineers are needed to provide leadership in the development of innovative and sustainable solutions to these challenges* [4].

Gilbuena, et al. [5] point out the unique framework of the capstone projects through which many possibilities are available:

> *"We argue that capstone projects can enculturate students in both disciplinary and industry communities of practice. Educators must identify the differences in the shared repertoire of these communities and frame curricular content and activities accordingly."*
> *Wherever possible, curriculum developers and instructors should employ an integrative approach where students can connect their use of professional skills directly to their technical work and the engineering objectives they pursue [5]*.

At this stage, we may clearly observe that when it comes to: a) integration of the professional component into the design and innovation process as well as b) strong consideration and incorporation of realistic constraints and standards, recommendations of ASME, ABET, and the engineering education community are very much in unison.

*Our primary goal in this presentation is multi-fold, as described below:*

1. *To share a promising model for implementation of Engineering Senior Projects,*
2. *To show how this model provides multiple platforms for conducting assessments,*
3. *Share what we have identified as potential areas for conducting such assessments,*
4. *Provide sample surveys (for such assessments) that have been configured to map into select ABET requirements, and*
5. *Share the promising results of such sample surveys and suggested mappings.*

**ABET and Student Outcomes**

Primarily, ABET provides guidelines and roadmaps that enable the engineering education community to align its goals and strategies toward delivering the needs and preferences of industry, society, and the entire globe. The agency states that:

*ABET accreditation assures the confidence that a collegiate program has met the standards essential to prepare graduates to enter critical STEM fields in the global workforce. Graduates from an ABET-accredited program have a solid educational foundation. They are capable of leading the way in innovation, emerging technologies, and anticipating the welfare and safety needs of the public [6].*

Student outcomes [6] describe what students are expected to know and be able to do by graduation. These relate to the knowledge, skills, and behaviors students acquire as they progress through the program. Without any interpretations, we list a summary of the most recent (ABET) Student Outcomes in Table (1) for reference.

**TABLE 1:** ABET Criterion 3 --- Student Outcomes

| # | Description of the Outcome |
|---|---|
| 1 | An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics |
| 2 | An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors |
| 3 | An ability to communicate effectively with a range of audiences |
| 4 | an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts |
| 5 | An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives |
| 6 | An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions |
| 7 | An ability to acquire and apply new knowledge as needed, using appropriate learning strategies |

A **Solid Foundation for Implementation of Senior Design Projects**

In 2012, the authors (who have collaboratively served as Senior Project Coordinators in their program) proposed a promising approach for better implementation of capstone Senior Design Projects [2]. We benchmarked against a considerable number of our sister institutions and aspirant programs. The presented model was based on several iterations over 11-12 years, leading to a reasonably balanced and practical approach. With another ten years of additional monitoring of 100+ Senior projects and Beta-testing, we invite you to examine a more refined and well-tested model and approach.

Table (2), a central piece in this work, shows a suggested model comprised of 33 sequential and synchronized steps for the formation of teams, implementation, and successful completion of Senior Projects. This is achieved through a series of continuously monitored tasks and reporting activities. Although not very broad, the industrial and consulting backgrounds of the two coordinators have enabled them to better simulate a real-world design and manufacturing-based environment. Consultation with members of our Industrial/External Advisory Council (IAC) has led to further calibration of this characteristic of the model.

As in the 2012 model, it proposes the early engagement of students in the process. As listed and described in Table (2), all rising Seniors are required to actively participate in fulfilling the first seven (7) steps of the process. Inviting the Rising Seniors to the Final Design Presentations of both SP-I and SP-II paves the road to a better understanding of the level of expectations and commitments in their near future culminating experience. On many occasions, in their Junior year, they choose to volunteer their time to projects they are interested in and gain valuable experience.

The model should prove particularly useful for programs that require a two-semester-long culminating Senior Design experience. Although it has been synthesized for a Mechanical Engineering program, it should be readily customizable for other sister programs with minimal effort and consumption of time.

To help engineering students gain fluency in professional skills, Shuman et al. (2005) advocated a new engineering education paradigm with the words of John Prados (1997), *who said this new paradigm should be "built around active, project-based learning; horizontal and vertical integration of subject matter; mathematical and scientific concepts in the context of application; close interaction with industry; broad use of information technology; and a faculty devoted to developing emerging professionals as mentors and coaches rather than all-knowing dispensers of information"* (Shuman et al., 2005) [5].

A close examination of the proposed model should reveal its complete alignment and compliance with the recommendations of ASME, ABET, and the Engineering Education Community.

**TABLE 2:** Process of Formation of Senior Project Teams, the Milestones, Reporting, and Presentations

| Step # | Description of the Steps and the Activities | Week # | Task and Period | |
|---|---|---|---|---|
| 1 | Information Session on Senior Projects (SPs) Presented to Rising Seniors | 7 | Formation of SP Teams | Junior 2nd Semester |
| 2 | Faculty and the Department Make the Detailed Descriptions, Requirements, and Professional Expectations of all SPs Available to the Students* | 6, 7, & 8 | | |
| 3 | Students Apply for their Top 2/3 Choices (of available/listed SPs) | 10 | | |
| 4 | Advisors Interview the Potential Members and Assemble the SP-Teams | 11 | | |
| 5 | The Expectations for each Project are Established and the Contracts Signed | 11-12 | | |
| 6 | Schedule of Weekly Activities, Meetings, the Preliminary Gantt Chart, and a Designated Project Website Created | 13-14 | | |
| 7 | Summer Research and the Potential Activities Discussed and Planned | 14-15 | | |
| 8 | Proposals Presented to the Entire (Departmental) Faculty and Peers | 2 | Project Management and Evolution of Design | Senior First Semester |
| 9 | Work on the Preliminary Design Starts and Continues for 6 – 8 Weeks | 1-8 | | |
| 10 | Log Books Reviewed & Critiqued on the 3rd Week (for Good Format & Practices) | 3 | | |
| 11 | Interim Designs are Presented to the Faculty and the Entire Class | 9-10 | | |
| 12 | Preliminary Budget Requests are Generated & Submitted to the SP-Coordinator | 10-11 | | |
| 13 | Budget Allocation Finalized and Shared with All Teams and Advisors | 11 | | |
| 14 | Design Decisions and Matrices Produced and Final Designs Conceived (with Consideration of Realistic Considerations, DFM, Man Power, etc.) | 11-12 | | |
| 15 | Working Drawings Generated by each Team | 8-11 | | |
| 16 | Working Drawings Reviewed by the corresponding Project Advisor(s) | 9-12 | | |
| 17 | Working Drawings Critiqued by the Manufacturing Supervisor(s) | 12-13 | | |
| 18 | Materials and Components Ordered | 11-14 | | |
| 19 | Final Design Presented to the Faculty, Peers, *and the Rising Seniors* | 14 | | |
| 20 | Design Report (for SP-I) and the Individual Log-Books Submitted to the Faculty Advisor for Evaluation, Critique, and Assessment | 14-15 | | |
| 21 | Team Members Conduct a Peer Evaluation | 15 | | |
| 22 | Registration into Competitions or Conferences Completed and Travel, Lodging, and Transport Arrangements Made | 10-15 | | |
| 23 | Teams Make Plans for Taking Advantage of the Semester Break | 11-15 | | |
| 24 | Teams Finalize Purchases and Crate a Conflict-Free Schedule for Manufacture | 1 | Prototyping, Testing, & Presenting | Senior Second Semester |
| 25 | Teams Present their Progress since the Last Presentation (9-10 weeks ago) | 2-3 | | |
| 26 | Teams Self-Assess, Intensify/re-plan Activities, and Complete their Prototypes | 3-10 | | |
| 27 | Teams Start Testing, Debugging, and Improving their Prototypes | 8-12 | | |
| 28 | Advisors Decide if the Products are Competition-Ready or Not | 13 | | |
| 29 | Final Design Presented to the Faculty, Peers, the Rising Seniors, and *I.A.C.*** | 14 | | |
| 30 | Teams Make Posters of their Projects and Showcase their Achievements (and Prototypes) in the Celebration of Student Achievements (COSA) Day | 13/14 | | |
| 31 | Along with the Log-Books, the completed Final (SP-II) Design Report is Submitted to the Faculty Advisor(s) for Evaluation and assessment | 14 | | |
| 32 | Team Members Make a Final Peer Evaluation | 15 | | |
| 33 | All Students Complete an Anonymous Mandatory Comprehensive Survey on their Overall Experience with their Senior Projects: *SP-Satisfaction Survey* | 15 | | |

* *Students may come up with their own proposal for a Senior Project and seek Faculty Sponsorship*
*** I.A.C.: Industrial Advisory Council*

**The Instrumental Roles of the Senior Professional and Senior Project Seminars**
It would be highly unlikely to implement the 33 steps displayed in Table (2) without the concurrent support and reinforcements of two Seminar courses.

These are *a) The Senior Professional Seminar* and b) *The Senior Project Seminar*. The former meets in the Fall semester (only) for 50-minutes per week. It covers a broad range of topics, including Engineering Ethics, Professional Preparations, and Expectations, Respect for the Environment and Practice of Green Engineering, and Continued Professional Growth. The latter (meeting for 50 minutes per week, both in Fall and Spring semesters) is in concert with the requirements and the steps listed in the table. It provides detailed information and guidance on successfully delivering and fulfilling the steps required for senior project tasks at hand. "Information Sessions" of these two seminars have proven to play a vital role in the effective implementation of the necessary steps in the sequence.

**Creation of Senior Projects and Formation of Optimal Teams**
Implementation of the recommended 33 steps starts with inviting all the Rising Seniors to a "Mandatory Information Session about Senior Projects" (Step #1/33).

Perhaps the two most important parameters in the successful implementation of Senior Projects are the Performance Requirements of the established projects and the optimal assembly of the teams. The symbiotic relationship between these two players may not be overemphasized. And while most of the 33 steps in the process are (relatively) intuitive and quite doable, these two parameters require both art/experience and dedication.

Whether a generic, Industry-based, or an ASME/SAE/IEEE-sponsored national/international competition project, the project constraints and requirements must be well balanced and expectations set at appropriate levels for the target audience. Both the background and the high dedication level of the faculty advisor(s) have to be in place. To enhance the chances of success, we offer a condensed summary of our recommendations in Table (3).

An optimal assembly (of the teams) is not necessarily a team comprised of academically high-performing individuals. According to Carl Smith [7], *"Base groups are long-term, heterogeneous cooperative learning groups with stable membership whose primary responsibility is to provide each student the support, encouragement, and assistance he or she needs to make academic progress"*. This is the transformation process that changes a group of individuals into a fully functioning, cohesive group [8].

In 1965, Bruce Tuckman [9] published his "Forming, Storming, Norming, and Performing" team development model. This elegant model has served as the basis for a host of similar models that have been developed in the almost six decades since its original publication. The Forming, Storming, Norming, and Performing stages of team development form a basis for understanding the team developmental process. A team must identify which stage they are in and manage the transition from one stage to another adeptly [8].

All individuals in a team are held accountable for the overall team performance. To learn that they will either all swim or all sink. While helping team members is encouraged, they are not allowed to hitchhike through others.

**TABLE 3:** Suggestions for Improving the Chances of Success for a Team-Based Project

| | Suggestions for Advisors to successfully Implement Senior Projects |
|---|---|
| **1.** | **Plan a comprehensive first meeting, reviewing all objectives, rules and regulations and logistical issues related to the project.** |
| **2.** | **Review the role of each member as an individual contributor and make it clear that the success of the team depends on the performance and dedication level of each of the members. *Swim Together or Sink Together.*** |
| **3.** | **Provide sources of information for conducting research and obtaining related literature.** |
| **4.** | **Inform the new team about the existing network of support for obtaining financial and professional assistance and sponsorship.** |
| **5.** | **Discuss the synergistic nature of the design and team work activities and provide examples of success and failure using prior experiences, etc.** |
| **6.** | **Set up a regular weekly time for group meetings that is compatible with every member's schedule and emphasize on the importance of participation of all members.** |
| **7.** | **Make them aware that a later change of design in one of the components/subsystems of the product may create a "Domino Effect" on many other components/subsystems.** |
| **8.** | **Have the entire team work with the project manager to generate a Gantt chart and a Critical Path Network.** |
| **9.** | **Have all members provide a progress report on weekly-basis and discuss/brainstorm the potential solutions for the newly encountered/unforeseen problems.** |
| **10.** | **Encourage members to finalize a (seemingly) flawless and promising design before they start fabrication.** |
| **11.** | **Encourage/require the team to test the functionality/practicality of their proposed designs by computer simulations and actual prototyping.** |
| **12.** | **Establish ample hours for the project, and make yourself available for all team members.** |
| **13.** | **Have the entire team make a presentation to previous year team members and all involved supporting individuals/collaborating advisors at critical stages of the project.** |
| **14.** | **Encourage the previous year team members to provide support and advice for the inexperienced team.** |
| **15.** | **Establish a rewarding and appreciation system for all the parties involved.** |

To better monitor their contributions, the team members must complete *"The Group Activities Evaluation Form/Peer Evaluation Form"* at the end of both SP-I and SP-II activities. This form is included in the Appendices as well.

To simulate an industrial climate, the selection of team members will be made after the advisor completes interviewing (the initially qualified) applicants (Steps 2 and 3 /33). If not familiar with the applicants' academic background, the proposal form (included in the Appendices) would help the process. Again, for this stage, we present a condensed summary of our recommendations in Table (4). Laguette's work on selecting teams for Capstone projects should be a good complement to what we have offered here [10].

**TABLE 4:** Suggestions for Planning the Project

| Planning the Project - Team Formation and Setting the Expectations | |
|---|---|
| **1.** | ***Evaluate the feasibility of conducting the project with regard to its required finances, human resources, equipment, facilities, deadline for completion, etc.***<br><br>***If not financially feasible, consider offering the "High-Cost" Legacy/Perennial Projects on an Alternating/ Biennial Basis.*** |
| **2.** | ***Recruit members that their interpersonal and intellectual skills complement each other.*** |
| **3.** | ***Set realistic expectations and challenge each member at a level that s/he may succeed.*** |
| **4.** | ***Prepare a preliminary timetable for major activities involved in the project.*** |
| **5.** | ***Establish a clear grading policy consistent with project's objectives and its requirements.*** |

**Mapping of the Selected Outcomes**

Among many sound recommendations of the ASME Vision 2030 task force, perhaps, the following is the most important one:

> *As we 'create the future for mechanical engineering education, we can not be prescriptive, with a 'one size fits all' template. We recognize that every ME department has to align their curricula with their overall institutional mission, whether it is a large land grant institution or a small private college. Therefore, the most important consideration in our recommendations is 'flexibility'. This consideration respects differences in institutional missions, the breadth of the mechanical engineering discipline, and accommodates the changing nature of engineering practice* [4].

So, it is important to note that we are in no way "prescriptive". Nor suggesting or implying that the "Assessment of Outcomes" may be limited or reduced to resources available in the spectrum of the activities in Capstone Senior Projects. Even if the model proves to be a rather comprehensive one, without prior preparations and "Continuous Improvements" on all aspects of the program, it will prove deficient throughout the four (4) years. This would be particularly evident in the assessment and the fine-tuning of the sequential progression/gains in both the design and the professional skill sets.

With this in mind, and for better viewing our choices, we first present a rather condensed description of the assessment process at our program.

In our case, we assess both laterally and vertically. Through extended retreats and multiple iterations and revisions, we have established the following method and approach for the assessment of outcomes:

1. Examine the suitability of every engineering-based course as a candidate for the "better" mapping of (any of the seven) outcomes. The courses are selected based on the High (H) and Medium (M) content contribution to a particular student outcome,

2. For every one of these courses, we have assigned a faculty (who usually conducts the course/laboratory),

3. The faculty create an End of the Semester report that examines the degree of success in achieving the objectives of every course (in number-1 above),

4. Each of these courses is assessed once every two years,

5. The results for each course are delivered to a central (electronic) depository,

6. At our retreats, the faculty share the details of their findings with the rest of the group,

7. If not satisfactory, we identify the problem(s) source and look for a change of strategy and remedies to correct/resolve the issue.

Tables (5) and (6) show the core and elective courses selected for the assessment and the frequencies of their examination in the Mechanical Engineering Program at TCNJ.

**TABLE 5:** Core and elective courses used in the assessment process

| Core courses: | Elective Courses: |
|---|---|
| ENG98: Fundamentals of Engineering Review | MEC 381: Introduction to Mechatronics |
| ENG99: Senior Professional Seminar | MEC 421: Kinematics & Mechanisms |
| ENG 232: Manufacturing Processes | MEC 431: Mechanical Design Analysis II |
| MEC 263: Mechanical Engineering Laboratory I | MEC 451: Heating, Ventilating & Air Conditioning |
| MEC 311: Mechanical Design Analysis | MEC 461: Thermal Systems Design |
| MEC 321: Numerical Analysis | MEC 470: Special topics |
| MEC 361: Fluid Mechanics | MEC 471: Compressible Fluid Mechanics |
| MEC 371: Thermodynamics II | MEC 481: Advanced Strength of Materials |
| MEC 411: Heat Transfer | MEC 483: Robotics |
| MEC 433: Mechanical Engineering Laboratory III | |
| MEC 460: Finite Element Analysis in Mechanical Design | |
| MEC 463: Mechanical Engineering Laboratory IV | |
| MEC 495/496: Senior Project I & II | |

With the revised ABET outcomes and the new additional requirements, we realized that it would be difficult to assess specific outcomes (such as S.O.s number 5 and number 7). So, we did further formalize the process of implementation of the Senior Projects so that: a) we may create additional avenues for conducting assessments, and b) such avenues would legitimately map into the examination of the new outcomes.

**TABLE 6:** Two-year cycle of course review in the ME program at TCNJ

| 2-Year Cycle of COURSE REVIEW in the ME PROGRAM | | | | |
|---|---|---|---|---|
| **Cycle of Review** | **Year 1** | | **Year 2** | |
| **Course** | **Fall 2019**<br>**Fall 2021**<br>**Fall 2023** | **Spring 2020**<br>**Spring 2022**<br>**Spring 2024** | **Fall 2020**<br>**Fall 2022**<br>**Fall 2024** | **Spring 2021**<br>**Spring 2023**<br>**Spring 2025** |
| ENG 232 [2]<br>MEC 321 [8]<br>MEC 460 [1, 2, 8] | **FALL RETREAT**<br>Fundamentals,<br>Modern Tools, and<br>Engineering Math.<br>**SOs Assessed: 1, 2, 8** | | | |
| MEC 311 [1, 2]<br>MEC 263 [3, 6]<br>MEC 463 [3, 6]<br>**All offered electives** | | **SPRING RETREAT**<br>Solid Mechanics Courses<br>and<br>Associated Laboratories<br>**SOs Assessed: 1, 2, 3, 6** | | |
| ENG 98 [4]<br>ENG 099 [4, 7]<br>MEC 495/496<br>[2, 3, 5, 7]<br>**All offered electives** | | | **FALL RETREAT**<br>Engineering Economics,<br>Ethics, and<br>Senior Design Project<br>**SOs Assessed:**<br>**2, 3, 4, 5, 7** | |
| MEC 371 [1, 2]<br>MEC 411 [1, 8]<br>MEC 433 [3, 6]<br>MEC 361 [1]<br>**All offered electives** | | | | **SPRING RETREAT**<br>Thermo-Fluids Courses<br>and<br>Associated Laboratories<br>**SOs Assessed:**<br>**1, 2, 3, [4], 6, [7]** |

With reference to the 33 steps [listed in Table (2)], we created survey instruments listed in Table (7) below. Although the rich resources identified in the foundation of the new model of implementation of the Senior Projects would enable us to examine all of the (ABET) S.O.s, we did not think we should resort to this resource only. Nor did we think it would be necessary to assess all S.O.s through this sole resource. We concluded that it might be more suitable to concentrate on using the Capstone Projects (<u>as one of the several available platforms</u>) for addressing S.O.s number: 2, 3, 5, and 7 (only). However, the addition of this particular resource has provided a level of comfort that otherwise may have proven problematic.

**TABLE 7:** Senior Project Surveys and Tools Utilized in the Assessment and the Mapping Process

| # | Survey for / Evaluation of: | Conducted by: | | | | Outcome # Mapped Into | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Students | S.P. Coord. | Faculty Advisor | All Departmental Faculty | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | Proposal Presentation | | √ | √ | √ | | | √ | | | | |
| 2 | Log-Books | | | √ | | | | | | | | √ |
| 3 | Interim Design Presentation | | √ | √ | √ | | | √ | | | | |
| 4 | Senior Project – I Presentation | | √ | √ | √ | | | √ | | | | |
| 5 | Senior Project – I Design Report | | | √ | | | √ | √ | | √ | | √ |
| 6 | Peer Evaluation for SP-I | √ | | | | | | | | √ | | |
| 7 | Progress Report | √ | | | | | | √ | | √ | | |
| 8 | Realistic Constraints and Standards | | √ | | | | √ | √ | √ | | | |
| 9 | Senior Project – II Presentation | | √ | √ | √ | | | √ | | | | |
| 10 | Senior Project – II Design Report | | | √ | | | √ | √ | | √ | | √ |
| 11 | Peer Evaluation for SP-II | √ | √ | √ | | | | | | √ | | |
| 12 | Final SP-Satisfaction Survey | √ | √ | | | √ | √ | √ | √ | √ | √ | √ |

As a sample and for illustration of the potency of the proposed process, here we present the application of the *Final SP-Satisfaction Survey*. Table (8) provides a detailed summary of the data collected throughout three (3) Academic Years. The ratings fluctuate between 80 to 90% in "all" of the selected Student Outcomes. The promising results are based on the activities through over 40 different Senior Project groups. Ninety-nine (99) out of the 100 (available) students participated in this survey.

**Table 8:** Summary of the Senior Project Satisfaction Survey for over 40 Different Projects

***Summary of Senior Project Satisfaction Survey for the AY: 2017-18 through 2021-22***

| Survey Results for the Year Academic Year of: | | | | S.O. # | Q # | Questions / Attributes | Most Important Attributes |
|---|---|---|---|---|---|---|---|
| 2017-18 N= 25/26 | 2018-19 N= 27/27 | 2020-21 N= 47/47 | 2021-22 N= 51/52 | | | | |
| 4.46/5 | 4.01/5 | 4.45/5 | 4.24/5 | 1 | 1 | Apply knowledge of mathematics, science, and engineering to solve challenging problems | Rank: #3 |
| | | | | | 2 | Apply knowledge from past coursework | |
| 89.2% | 80.3% | 89.0% | 84.8% | | 3 | Utilize modern engineering tools and techniques to solve an engineering problem | Rank: #4 |
| | | | | | 4 | Use of computational tools for analysis and optimization of design | |
| | | | | | 5 | Analyze and interpret data | |
| 4.51/5 | 4.11/5 | 4.53/5 | 4.27/5 | 2* | 6 | Design a component or system to meet desired needs | |
| | | | | | 7 | Build prototypes and working models | Rank: #1 |
| 90.2% | 82.3% | 90.6% | 85.3% | | 8 | Include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, and social & environmental impact | |
| 4.21/5 | 4.41/5 | 4.59/5 | 4.51/5 | 3* | 9 | Communication through oral presentations and written reports | Rank: #5-Shared |
| 84.2% | 88.2% | 91.8% | 90.2% | | | | |
| 4.32/5 | 4.11/5 | 4.47/5 | 4.29/5 | 4 | 10 | Recognize professional and ethical responsibilities and consider the potential adverse effects of engineering solutions | |
| 86.4% | 82.3% | 89.4% | 85.8% | | | | |
| 4.32/5 | 4.11/5 | 4.47/5 | 4.39/5 | 5* | 11 | Function on a team | Rank: #2 |
| | | | | | 12 | Recognize and apply good practices in Project Management | |
| 86.4% | 82.3% | 89.4% | 87.7% | | 13 | Interaction with team members | |
| Not Req. By ABET in 2017-18 | NA | | | 7* | 14 | Conduct Background Research | |
| | | 4.40/5 | 4.27/5 | | 15 | Consider and Generate Alternative Designs | |
| | | 88.0% | 85.4% | | 16 | Acquire and Apply New Knowledge and Skills as needed | Rank: #5-Shared |
| X | X | 4.10/5 | 3.33/5 | No Mapping | 17 | Availability and Interaction with the senior project advisor | |
| X | X | 4.02/5 | 3.17/5 | // | 18 | Technical assistance/guidance provided by senior project advisor | |
| X | X | 4.00/5 | 3.80/5 | // | 19 | Process of Formation of Teams and Availability of Projects | |
| X | X | 4.29/5 | 4.29/5 | // | 20 | Instructions and Guidelines provided by the SP-Coordinator | |
| X | X | 4.33/5 | 4.61/5 | // | 21 | Availability of the Dedicated SP Space and the Manufacturing Facilities | |
| X | X | 4.49/5 | 4.63/5 | // | 22 | Availability of the Requested Budget for Your Project | |
| X | X | 4.24/5 | 4.14/5 | // | 23 | Guidance and Assistance (as needed) in the Manufacturing of SP | |
| X | X | 4.29/5 | 4.35/5 | // | 24 | Your Overall Experience with Your Senior Project | |

* → *S.O.s Chosen for Mapping Based on Departmental Recommendations/Decisions*

**Summary**

We have proposed a model for implementing Engineering Senior Projects that serve as a multi-level platform allowing for launching surveys that may measure the level of success in achieving the goals of engineering programs.

The 33 steps described for implementing the proposed model should enable the interested colleagues to examine its potential adoption for their programs. The model has been created through three (3) decades of iterations and improvements. Although the model has been synthesized for a Mechanical Engineering program, it should be readily customizable for other sister programs with minimal effort and consumption of time.

ASME and ABET have converging statements regarding the integration of Professional Experience with Design and Innovation. A close examination of the proposed model should reveal its complete alignment and compliance with the recommendations of these leading authorities.

A good number of the activities embedded in the proposed sequence of implementation serve as legitimate candidates for conducting clear and practical assessments. There are ample avenues to explore and choose from. These may be a mixture of both quantitative and qualitative methods of assessment. A sample of clear mapping (of ABET SOs,) is presented. A summary of the promising results of surveys conducted over 40 different Senior Projects at three iterations is provided. In the Appendices, in addition to a comprehensive proposal form, we have included ample samples of guidelines provided (to the SP-students) and surveys conducted at particular intervals/for relevant activities.

Should the paper be well-received, the authors would eagerly conduct a workshop for sharing the full spectrum of the details embedded in the proposed model and process.

**Conclusion**

Through a balanced, comprehensive, and well-tested model for Undergraduate Engineering Senior Projects implementation, many legitimate assessment avenues would become available. However, while the Senior Project experience and process provide some rather unique opportunities, this should not be the only source for conducting such assessments.

The quality, type, and balanced scope of the Senior Projects and the process of the formation of the teams are instrumental in their successful implementation and completion. The control and proper creation of this symbiotic relationship are critical factors in the process.

There should be no prescriptive processes if we understand that every program is unique. The accreditation agency-ABET and ASME, are quite aware of this broad spectrum of program sizes, attributes, and limitations. They provide guidance and roadmaps that help enhance engineering education leading to a more prepared engineering workforce.

**Acknowledgments**
The authors wish to acknowledge the inputs received from the faculty of the mechanical engineering department of their affiliation.

## Bibliography

[1] B. Sepahpour and N. Asper, "A Promising Model for Integrating Design in Undergraduate Engineering Curriculum": *Proceeding of ASEE 2001 National Conference, Albuquerque, NM, June 2001.*

[2] M. Paliwal and B. Sepahpour, "A Revised Approach for Better Implementation of Capstone Senior Design Projects": *Proceedings of ASEE 2012 National Conference, San Antonio, TX, June 2012.*

[3] J.R. Goldberg, *Capstone design courses producing industry-ready biomedical engineers,* CA : Morgan & Claypool Publishers, 2007.

[4] ASME Vision 2030: "Creating the Future of Mechanical Engineering Education, Phase 1 Report": ASME Center for Education Task Force, December 15, 2010.

[5] D.M. Gilbuena, B.U. Sherrett, E.S. Gummer, A.B. Champagne, and M.D. Koretsky, "Feedback on Professional Skills as Enculturation into Communities of Practice": *Journal of Engineering Education,* Vol 104 No. 1, pp. 7-34, Jan. 2015.

[6] *Criterion 3: Student Outcomes – ABET 2018 Criteria*

[7] C.A. Smith, "Effective Teamwork for Engineering Classrooms": Workshop proceedings, *Re-Engineering Engineering Education, Rensselaer Polytechnic Institute, 1995.*

[8] N. Asper and B. Sepahpour, "Utilizing Team Building Skills in Engineering Projects": *Proceedings of ASEE 2003 National Conference, Nashville, TN, June 2003.*

[9] B.W. Tuckman, "Development Sequence of Small Groups",*: Psychological Bulletin, 1965, Vol. 63, No.6, 384-399.*

[10] S. Laguette, G., "*Development of High Performance Capstone Project Teams and the Selection Process",* Colorado : Capstone Design Conference, 2010.

## *Appendices*

| *The following Appendices provide:*<br><br>*A) Samples of the guidelines for better implementation of the Senior Projects and*<br>*B) Samples of Surveys for collection of data and mapping into the Outcomes* | | | |
|---|---|---|---|
| **Designation** | **Description** | **# of Pages (shown Here)** | **Original # of Pages** |
| **A** | **List of the AY 2021-22 Senior Design Projects and a sample of the schedule of Presentations** | **1** | **2** |
| **B** | **The Proposal Form for Applying to a Senior Design Project** | **3** | **6** |
| **C** | **Peer Evaluation of Professional Responsibilities** | **1** | **1** |
| **D** | **A Sample of the Rubrics and Surveys used in the Assessment of the Quality of the Presentations** | **1** | **1** |
| **E** | **Evaluation of the Written Senior Project Reports and the Selected Outcomes for Mapping** | **1** | **2** |
| **F** | **Guidelines for the Contents and Format of Final Design Presentations** | **2** | **4** |
| **G** | **Evaluation of the Progress on Senior Projects (since the last presentation)** | **1** | **1** |
| **H** | **Senior Project Satisfaction Survey – Blank Form** | **1** | **1** |

*Appendix - A*

**List of the AY 2021-22 Senior Projects and a sample of the schedule of Presentations**

**Mechanical Engineering *Senior Project-II: Final Design* Presentations**

**Wednesday, May 4th, 2022 ----- *Education Building - 115***

| # | Team/Project | Presentation Period | Team Members | Advisor(s) |
|---|---|---|---|---|
| 0 | Introduction | 8:50 – 9:05 AM | *Breakfast, Loading of the Presentations, and Silent Mode of E-Devices* | ---------- |
| 1 | TCNJ - ASME HPVC – 2021/2022 | 9:05 – 9:20 AM + 4 Minutes of Q&A | 1. Jermar Best * – Mechanical Engineering<br>2. Jake Falleni – Mechanical Engineering<br>3. Christopher Fornarotto – Mechanical Engineering<br>4. George (Eli) Gabriel ** – Mechanical Engineering<br>5. Zachary Leong – Mechanical Engineering | Dr. Asper<br>Regina Cadillac<br>Dr. Grega |
| 2 | Modular Adaptable Desk | 9:25 – 9:36 AM + 3 Minutes of Q&A | 1. Hannah Corbisiero * & ** – Mechanical Engineering<br>2. Ishan Lyn – Mechanical Engineering<br>3. Victoria Yuknek – Mechanical Engineering | Dr. Paliwal<br>Prof. Sepahpour |
| 3 | Cargo Rack Easy Access Design (CREADs) | 9:40 – 9:51 AM + 3 Minutes of Q&A | 1. Leah Hill * – Mechanical Engineering<br>2. Jennifer LaRocca ** – Mechanical Engineering<br>3. Joe Felipe – Mechanical Engineering | Dr. Paliwal<br>Dr. Shih |
| 4 | TCNJ – SAE- Aero-Design 2021/2022 | 9:55 – 10:08 AM + 4 Minutes of Q&A | 1. Zackary Hirschman – Mechanical Engineering<br>2. Adam Musa * – Mechanical Engineering<br>3. JP Prioli – Mechanical Engineering<br>4. Brian Slack ** – Mechanical Engineering | Dr. Grega |
| 5 | Ankle Foot Orthotic Device | 10:13 – 10:24 AM + 3 Minutes of Q&A | 1. Tyler Booth – Mechanical Engineering<br>2. Julia Connelly * – Mechanical Engineering<br>3. Tina Williams ** – Mechanical Engineering | Dr. Paliwal |
| 6 | Ski and Snowboard Training System | 10:28 – 10:39 AM + 3 Minutes of Q&A | 1. Jameson Dugan * – Mechanical Engineering<br>2. Haoyu Ji * – Mechanical Engineering<br>3. Daniel Kelly * – Mechanical Engineering | Prof. Sepahpour |
| | *A 10-Minute Break* | *10:42 – 10:52 AM* | *A Short Break and maintaining Silent Mode of E-Devices* | --------- |
| 7 | TCNJ - Intelligent Ground Vehicle Competition (IGVC)—2021-22 | 10:52 – 11:01 AM + 3 Minutes of Q&A | 1. Stephen Coleman * – Mechanical Engineering<br>2. Stefan Delafave ** – Mechanical Engineering | Dr. Wang |
| 8 | Digital Twin for Pump Cavitation | 11:05 – 11:16 AM + 3 Minutes of Q&A | 1. Jack Ennis * – Mechanical Engineering<br>2. Willian Tenempaguay ** – Mechanical Engineering<br>3. Kyle Dade – Mechanical Engineering | Dr. Grega<br>Dr. Alabsi |

*→ Team Manager/Team Leader/Team Coordinator/Co-Leader

**→ Website Developer

*Continued on the Back*

**Mechanical Engineering *Senior Project-II: Final Design* Presentations --- Continued**

| # | Team/Project | Presentation Period | Team Members | Advisor(s) |
|---|---|---|---|---|
| 9 | Drop-Weight Based Low Velocity Impact Tester with Imaging Capabilities | 11:20 – 11:31 AM + 3 Minutes of Q&A | 1. Michael Oudenne * – Mechanical Engineering<br>2. Michael Iannotta ** – Mechanical Engineering<br>3. Daniel Villardi – Mechanical Engineering | Dr. Yan |
| 10 | Instrumentation of 3-D Truss and Re-Tooling of the 3-Station Fatigue Tester | 11:35 – 11:44 AM + 3 Minutes of Q&A | 1. Rodney Noel * – Mechanical Engineering<br>2. Michael Erickson * & ** – Mechanical Engineering | Prof. Sepahpour |
| 11 | TCNJ Mini Baja - 2021/2022 | 11:48 – 12:01 PM + 4 Minutes of Q&A | 1. Jack Bishop * – Mechanical Engineering<br>2. Isabella Corry * – Mechanical Engineering<br>3. Jonathan Karcher * – Mechanical Engineering<br>4. Bryan Tran * & ** – Mechanical Engineering | Dr. Asper<br>Regina Cadillac<br>Prof. Sepahpour |
| | *A 10-Minute Break* | *12:05 – 12:15 PM* | *A Short Break and maintaining Silent Mode of E-Devices* | --------- |
| 12 | Motorized Flyer Stand | 12:15 – 12:26 PM + 3 Minutes of Q&A | 1. Lyndsey Corsi * – Mechanical Engineering<br>2. Sarah Esposito ** – Mechanical Engineering<br>3. Taylor Stafford * – Engineering Science (ME) | Dr. Alabsi |
| 13 | TCNJ Solar Splash - 2021/2022 | 12:30 – 12:43 PM + 4 Minutes of Q&A | 1. Grace Rutyna * – Mechanical Engineering<br>2. Matthew Leggett * – Mechanical Engineering<br>3. Christina Reichwald * – Mechanical Engineering<br>4. Lucas Austin ** – Mechanical Engineering | Dr. Asper<br>Regina Cadillac<br>Dr. Yan |
| 14 | Phoenix Mug | 12:48 – 12:59 PM + 3 Minutes of Q&A | 1. Jess Ruby * – Mechanical Engineering<br>2. Jason Rosen * & ** – Mechanical Engineering<br>3. Brett Murphy * – Mechanical Engineering | Dr. Alabsi |
| 15 & | Robotic Lawn Mower/ Autonomous Lawn Care | 1:04 – 1:19 PM + 4 Minutes of Q&A | 1. Ella Hofstetter * – Mechanical Engineering<br>2. Jared Green ** – Mechanical Engineering<br>3. Brett Flynn ** – Mechanical Engineering<br>4. Cesar Garriga – Mechanical Engineering<br>5. Alvin Paul - Engineering Science (ME) | Dr. Wang |
| 16 | Shear cutters for Autonomous Lawn Care | 1:24 – 1:31 PM + 3 Minutes of Q&A | Sameer Zaki – Mechanical Engineering | Dr. Wang |
| 17 | Autonomous Photography Drone (APD) [Multi-Disciplinary (ME & *ECE*)] | 1:35 – 1:48 PM + 4 Minutes of Q&A | 1. William Apostolico – Mechanical Engineering<br>*2. Fabian Mestanza – E/CE*<br>*3. Alexander Bolen – E/CE*<br>*4. Evan Hope – E/CE* | Dr. Alabsi<br>*Dr. Adegbege* |

*→ Team Manager/Team Leader/Team Coordinator/Co-Leader

**→ Website Developer

*Starting on the Other Side*

## *Appendix-B*
## The Proposal Form for Applying to a Senior Design Project

**The College of New Jersey**
***Mechanical Engineering Department***
**Senior Project Proposal***

| **Date the Proposal Received: →** | / / | **Proposal Accepted** | |
|---|---|---|---|
| | | **Proposal Rejected** | |

| **Title of the Project →** | | |
|---|---|---|
| **Duration of the Projects** | **Fall** | **Spring** |

| Student # | Student Name / Team Members (PRINT) | Student e-mail | Student Major | 1. Primary Advisor** / 2. Collaborating Advisor — Name and Signatures | *If None, Circle →* |
|---|---|---|---|---|---|
| 1 | | @tcnj.edu | | 1. | |
| | | | | 2. | *NA* |
| 2 | | @tcnj.edu | | 1. | |
| | | | | 2. | *NA* |
| 3 | | @tcnj.edu | | 1. | |
| | | | | 2. | *NA* |
| 4 | | @tcnj.edu | | 1. | |
| | | | | 2. | *NA* |
| 5*** | | @tcnj.edu | | 1. | |
| | | | | 2. | *NA* |
| 6*** | | @tcnj.edu | | 1. | |
| | | | | 2. | *NA* |

* See ***Appendix-A*** for "Basic Requirements" for signing up into a Senior Project.

** Unless approved by both the Chairperson and the SP Coordinator, for multi-disciplinary projects, every student engaged in such a Senior Project must have an advisor from his/her specific major. Industry Advisors are welcome but may not substitute a Departmental Advisor.

*** Formation of teams with more than four (4) members from the Mechanical Engineering department, including Engineering Management with Mechanical Engineering preference must be approved by the Chairperson of the program.

**Place a Check Mark ( ✓ ) in your boxes for**
**The Courses Required to be Completed by the end of the Summer Prior to the Start of your SP**

| *Course Code and Title* | *(Your) Student # as Listed in the Table on the First Page of this Proposal Package* — Student #1 | Student #2 | Student #3 | Student #4 | Student #5 | Student #6 |
|---|---|---|---|---|---|---|
| *ENG 232 Manufacturing Processes* | | | | | | |
| *ENG 342 Adv. Math-II* | | | | | | |
| *MEC 311 Mech. Design-I* | | | | | | |
| *MEC 321 Numerical Methods* | | | | | | |
| *MEC 361 Fluid Mechanics* | | | | | | |
| *MEC 363 Mech. Lab-II* | | | | | | |
| *MEC 371 Thermo-II* | | | | | | |
| *ME Elective you have taken* List the Title →→ | | | | | | |
| *Additional Relevant Course #1* List the Title →→ | | | | | | |
| *Additional Relevant Course #2* List the Title →→ | | | | | | |

| **Department Chairperson Approval for Projects with more than Four (4) Members** | **Signature:** |
|---|---|
| **Senior Project Coordinator's Approval for any of the Projects** | **Signature:** |

## *Appendix-B --- Cont.*

**Proposed Grading Form**

**Senior Project - I**

| Topic | % (min) | % (actual) † | Grading | T/I ǂ | Comment |
|---|---|---|---|---|---|
| Project Proposal | 5% | | | T | Identify Need, Analysis, and Frame Design Brief (as well as Presentation Technique) |
| Interim Design Review | 5% | | | I | Planning, Investigation, and Alternative Solutions (as well as Presentation Technique) |
| Final Design Presentation | 10% | | | I | Final Design, Documentation, Presentation Technique |
| Project Planning | 5% | | | T | Budget, Schedule, and Project Planning (such as application of Critical Path Networking) |
| Technical Merit | 15% | | | I | Complexity, Execution, Degree of Difficulty, Quality, Potential for Invention & Innovation |
| Contribution to Project | 10% | | | I | Peer Review --- Evaluated by other team members |
| Record Keeping and Log-book | 10% | | | I | Organization of the Log-book and the quality of the contents --- Evaluated by faculty advisor |
| Final Design Report | 15% | | | I | Content, Organizations, Format, Style |

---

**Senior Project - II**

| Topic | % (min) | % (actual) † | Grading | T/I ǂ | Comment |
|---|---|---|---|---|---|
| Testing / Validation Plan | 5% | | | T | Effectiveness of Testing / Validation Process |
| Testing / Validation Execution | 5% | | | T | Overall Success of Testing, Data Collection, Readiness for Competition and / or Presentation |
| Project Planning | 10% | | | T | Degree of Success in Implementation of Cost/ Benefit Analysis, Schedule, and Critical Path Network |
| Final Design Presentation | 5% | | | I | Final Design, Documentation, Presentation Technique |
| Technical Merit | 15% | | | I | Complexity, Execution, Degree of Difficulty, Quality, Potential for Invention & Innovation |
| Contribution to Project | 10% | | | I | Peer Review --- Evaluated by other team members |
| Timely and Successful Completion of the Project/Prototype ✪✪ | 20% | | | T | Quality of the Workmanship and Testing for Reliability of the Finished Product and Readiness to Represent TCNJ at Competitions/ Conferences/ etc. |
| Final Design Report and the Log-book | 15% | | | I | Content, Organization, Format, Style |

† Advisor(s) and student(s) need to agree upon and fill in the actual percentages before submission of the proposal

ǂ T → Team Grade, I → Individual Grade

✪✪ See Appendix "B"

**Agreement**

**on the**

**"Grade Distribution and Deliverables"**

| Student #s *[As listed in the 1st Page]* | Student Name / Team Members (PRINT) | Student Signature |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

| Primary Advisor Name | Signature |
|---|---|
| | |

| Collaborating Advisor Name | Signature |
|---|---|
| | |

*Appendix-B --- Cont.*

**Attachments:**

1. On a separate sheet, and with the input, review, and **approval** of the Project Advisor(s) **the team** needs to describe:

   A) The Overall Project and the Performance Requirements that need to be addressed,
   B) Proposed Team Outcomes, and
   *C)* Deliverables. *[Range: 80 to 120 words --- **Typed]***

2. On a separate sheet and (again) with the input, review, and **approval** of the Project Advisor(s), **each** team member will describe:

   A) his/her specific role(s) and responsibilities in the project,
   B) Proposed Individual Outcomes, and
   *C)* Individually (focused) Deliverables. *[Range: 80 to 120 words --- Typed]*

3. Proposed Grading Form
This form needs to be reviewed by the student(s) and the advisor(s) and the details of the expectations clearly discussed. The actual Percentages need to be established and agreed upon. *Total must add up to 100%.*

4. All of the above forms need to be attached to the proposal. Additional parameters/requirements may be added by the advisor(s).

---

**Appendix: A**

**Basic Requirements**

1. All students applying for a Senior Project must have "Senior Standing".

2. Senior Standing is not defined by the number of credits earned. ***Senior Standing is defined by the applying student having followed the sequence of the courses required in the program (and clearly listed in the M.E. Program Planner) and completely (and successfully) caught-up with "all" of them.***

3. The requirement described in the previous step (#2) may only be waived when and if "both" the sponsoring advisor(s) and the Senior Project Coordinator of the department agreeing to it.

4. The advisors for specific projects may require certain courses to have been completed "successfully" [and possibly at a certain rate of success] before the applying student is admitted into the project/join the rest of the team.

5. Suggested memberships for different teams may or may not be initiated by the students. However, the final decision on the formation of a team [and the number of team members required for the implementation of a particular project] is *entirely at the discretion of the sponsoring advisor(s)*. The advisor(s) would interview all of the interested applicants and finalize the composition of the team based on: a) students' background and experiences, b) past performances, and c) the potential to provide the expected level of synergistic interactions and contributions. Such an approach may be taken for both the perennial as well as all other types of projects. See ***Appendix-C*** for a Sample of the Interview Questions.

6. In harmony with our Accreditation Agency (ABET); the ME faculty has the following expectations:
"Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political."

*Appendix-C*

**Peer Evaluation of Professional Responsibilities**

**Peer Evaluation Form: Team Member's Professional Responsibility** **Evaluator:** ______________________

**How Closely *(above or below the assigned percentages/points shown)* the team members met the expected responsibility**

| Criteria for Evaluation ↓ / Member's Name → | | *Team Member #1* | *Team Member #2* | *Team Member #3* | *Team Member #4* | *Team Member #5* | *Team Member #6* |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Positive Interdependence**<br>This member recognized that the team will Sink-or-swim together:<br>**1.** Agreeing on answer(s)/strategies for each problem,<br>**2.** Fulfilling assigned role responsibilities,<br>**3.** Recognizing "Common Rewards",<br>**4.** Acknowledging "Shared Resources", and<br>**5.** Complying with "Division of Labor". | | **/ 15** | **/ 15** | **/ 15** | **/ 15** | **/ 15** | **/ 15** |
| **Face-to-Face Promotive Interaction**<br>This member explained *orally* to the other (members):<br>**1.** How to solve problems,<br>**2.** The concepts & strategies being used, and<br>**3.** The connections between present and past experiences. | | **/ 20** | **/ 20** | **/ 20** | **/ 20** | **/ 20** | **/ 20** |
| **Individual Accountability** | This member was held individually accountable for his/her share of the work. | **/ 10** | **/ 10** | **/ 10** | **/ 10** | **/ 10** | **/ 10** |
| | This member, throughout the project period, participated in the assessment of the work of the other group members and shared his/her thoughts with the rest of the group. *The group needs to know who needs more assistance.* | **/ 10** | **/ 10** | **/ 10** | **/ 10** | **/ 10** | **/ 10** |
| | This member recognized that none of the members could "hitch-hike" on the work of the other members. | **/ 20** | **/ 20** | **/ 20** | **/ 20** | **/ 20** | **/ 20** |
| **Teamwork Skills**<br>This member possessed and used:<br>**1.** Leadership skills<br>**2.** Decision making skills<br>**3.** Trust-building skills<br>**4.** Communication skills<br>**5.** Conflict-management skills | | **/ 25** | **/ 25** | **/ 25** | **/ 25** | **/ 25** | **/ 25** |
| ***Total*** → | | **/100** | **/100** | **/100** | **/100** | **/100** | **/100** |

*Appendix-D*

**A Sample of the Rubrics and Surveys used in the Assessment of the Quality of the Presentations**

**MEC-495 / Senior Project-I**

**Guidelines/ Recommendations/ Requirements/ Rubrics for SP-I Proposal Presentations**

The following suggested guidelines (listed in the table) should provide a roadmap for creation of your MEC 495 /SP-I "Proposal Presentation".
*Please note that your faculty advisor(s) may choose to add, change, modify these recommendations/instructions.*

| # | | Guidelines/ Recommendations/ Requirements/ Rubrics | Advisor(s) & ME Faculty Evaluation |
|---|---|---|---|
| 1 | A | It is evident that All Team Members Participated in the Creation of this Highly Structured PowerPoint Presentation. | / 5 |
| | B | Quality of the Delivery was high and transition from one area/member to another was seamless. | / 5 |
| | C | Quality of the graphics was high. The slides were numbered and the contents were well-balanced and well-spaced. | / 5 |
| | D | Every member demonstrated Good Choices of Words, adequate Voice Projection, and reasonable Eye Contact. | / 5 |
| | E | The team made an optimal use of time and did not exceed their allotted time. | / 5 |
| | F | It was clear that this team has spent the necessary time and put in the effort to well prepare for this presentation. | / 5 |
| 2 | | The team clearly described: The Primary "Goals and Expectations" from:<br>i- the entire team and<br>ii- each individual member on the team.<br><br>In this step, the team clearly described:<br>i- the Performance Requirements and Competition Rules (if applicable) of the project,<br>ii- The Design Challenges ahead, and<br>iii- the agreed upon/expected level of deliverables. | / 4 0 |
| 3 | | The team clearly described its course of action and presented a reasonable and realistic preliminary plan/schedule of activities/Gantt Chart. | / 1 5 |
| 4 | | The team and the individual members responded reasonably well to the raised questions/concerns. | / 1 5 |

| | | | | |
|---|---|---|---|---|
| Presentation # → → → | [ ? ] | Project Title: ____________ | Total → → | / 1 0 0 |

*Appendix-E*

## Evaluation of the Written Senior Project Reports and the Selected Outcomes for Mapping

**Evaluation of the Final SP-I Report**
**Fall 2020**

| Project Title: | Mars Rover and Rock Retriever |
|---|---|
| Students | 1. John Doe-I<br>2. John Doe-II<br>3. John Doe-III |
| Advisor | Prof. Francis Bacon |

| Mapped S.O. # | Level and Quality of the Evidence Reflecting on: | % Allocated | Total % Met | 0, 1, Or 2? |
|---|---|---|---|---|
| 2 | Designing a component or system to meet desired needs | 57 / 70 | 81.5 | 2 |
| | Inclusion/Consideration of a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, and social & environmental impact | 24.5 / 30 | | |
| 3 | Communication through oral presentations and written reports | 80 / 100 | 80 | 2 |
| 5 | Function on a team | 38 / 40 | 89 | 2 |
| | Recognizing and applying good practices in Project Management | 24 / 30 | | |
| | Interaction with team members | 27 / 30 | | |
| 7 | Conducting Background Research | 25.5 / 30 | 84.5 | 2 |
| | Considering and Generating Alternative Designs | 27 / 30 | | |
| | Acquiring and Applying New Knowledge and Skills as needed | 32 / 40 | | |

**Evaluation of the Final SP-II Report**
**Spring 2021**

| Project Title: | Mars Rover and Rock Retriever |
|---|---|
| Students | 1. John Doe-I<br>2. John Doe-II<br>3. John Doe-III |
| Advisor | Prof. Francis Bacon |

| Mapped S.O. # | Level and Quality of the Evidence Reflecting on: | % Allocated | Total % Met | 0, 1, Or 2? |
|---|---|---|---|---|
| 2 | Designing a component or system to meet desired needs | 34.5 / 40 | 86.5 | 2 |
| | Building prototypes and working models | 35.5 / 40 | | |
| | Inclusion/Consideration of a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, and social & environmental impact | 16.5 / 20 | | |
| 3 | Communication through oral presentations and written reports | 88 / 100 | 88 | 2 |
| 5 | Function on a team | 38 / 40 | 92 | 2 |
| | Recognizing and applying good practices in Project Management | 26 / 30 | | |
| | Interaction with team members | 28 / 30 | | |
| 7 | Conducting Background Research | 26 / 30 | 90 | 2 |
| | Considering and Generating Alternative Designs | 28 / 30 | | |
| | Acquiring and Applying New Knowledge and Skills as needed | 36 / 40 | | |

*Appendix-F*

# Guidelines for the Contents and Format of Final Design Presentations

## Guidelines / Recommendations / Requirements for the SP-I --- Final Design Presentations

The following suggested guidelines and table should provide a roadmap for creation of your "Final Design Presentation" in MEC 495 / SP-I. Please note that your faculty advisor(s) may choose to add, change, modify these recommendations/instructions.

I - In general, you need to come up with a highly structured set of PowerPoint Slides that describe: a) the project goals, b) the milestones set, and c) your degree of progress and success up to this point of your Senior Project experience (since its formation and sponsorship).

II – The contents of the table are primarily built on the prior instructions provided to you for: *a) Your Proposal Presentations* and *b) Your Interim Design Presentations* (in SP-I). So, you should identify the relevant slides from those two presentations for inclusion in this one. However, you may need minor/major enhancement/modifications of such slides prior to inclusion!

III- At this point, all teams have received detailed instructions on the expectation for the SP-I report. [Again, as stated on those instructions, faculty advisor(s) may choose to add, change, modify those instructions.] As you are nearing the completion of the different segments of that report, you should be in a position to selectively bring out the highlights of your accomplishments as a group and/or as an individual.

IV – Although the table below contains a minimalist reflection of the expected contents of your presentation, the sequence is not necessarily in a specific order. You should use good judgement in fine-tuning the best order for your specific areas and specific project.

**MEC 495 --- Recommendations / Requirements for the SP-I --- Final Design Presentations**

| Step # | *Advisor(s) position regarding this step* | *Use a √ Mark Or Leave Blank* | *Description of the Recommendation / Requirement* |
|---|---|---|---|
| **1 – A** | *Advisor(s) Concur with and Require this Step* | | **All Team Members Participate in the Creation of a PowerPoint Presentation***<br>* → Refer to the Handout for Good Practices in Presentations |
| **1 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **2 – A** | *Advisor(s) Concur with and Require this Step* | | **The team describes: *a) the "Goals /Performance Requirements /Competition Rules" of the project and b) the agreed upon/expected level of delivery.*** |
| **2 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |

***MEC 495 --- Recommendations / Requirements for the SP-I --- Final Design Presentations --- Continued***

| Step # | *Advisor(s) position regarding this step* | *Use a √ Mark Or Leave Blank* | *Description of the Recommendation / Requirement* |
|---|---|---|---|
| **3 – A** | *Advisor(s) Concur with and Require this Step* | | **The presentation needs to reflect on the direction that the team has taken onto "which design they have decided upon" and "the degree of success" they have achieved towards achieving the relevant goals.** |
| **3 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **4 – A** | *Advisor(s) Concur with and Require this Step* | | **The team presents:**<br>**a) The preliminary research and Literature Review,**<br>**b) The steps in applying scientific and engineering principles in the "Mathematical Modeling" of the system(s) at hand, and**<br>**c) Provide examples of work on "Analytical Optimization".** |
| **4 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **5 – A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to demonstrate the "Alternative Designs" considered and a realistic "Design matrix" for justification of the preferred/most practical/most feasible design (influenced by parameters such as: Availability of Materials, Competition Rules, Manufacturing Limitations, Budgetary Constraints, anthropometrics, Human Resources, Deadlines to meet, etc.).** |
| **5 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **6 – A** | *Advisor(s) Concur with and Require this Step* | | **Your team may choose to present "sample" Preliminary (Free-Hand) drawings reflecting on the evolution and the iterative sequence of the changes and the progress made toward the final designs.** |
| **6 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **7 – A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to present "sample" Professional/Working drawings reflecting on the degree of progress made on the completion of the design (including drawings of each subsystem and the complete meshing and assembly of the entire design).** |
| **7 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |

## *Appendix-F--- Cont.*

| *MEC 495 --- Recommendations / Requirements for the SP-I --- Final Design Presentations --- Continued* | | | |
|---|---|---|---|
| **Step #** | ***Advisor(s) position regarding this step*** | ***Use a √ Mark Or Leave Blank*** | ***Description of the Recommendation / Requirement*** |
| **8 – A** | *Advisor(s) Concur with and Require this Step* | | **Your team needs to present applications of FEM for analysis, determination of the Factor of Safety, and possible changes in the design (due to these findings).** |
| **8 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **9 – A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to present the different "Manufacturing" modes considered and justify the final selection made (perhaps within Realistic Constraints).** |
| **9 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **10 - A** | *Advisor(s) Concur with and Require this Step* | | **Your team needs to present applications of Solid Modeling in the Design Process and (possibly) the use of the animation features in confirming the design.** |
| **10 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **11 - A** | *Advisor(s) Concur with and Require this Step* | | **The Total Budget of the Project? The sources for the budget? Initial estimation as compared with the current assessment? What portion of the budget exhausted?** |
| **11 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **12 - A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to describe how the project has been influenced by "Realistic Constraints" and what considerations it has taken towards incorporation of relevant "Standards".** |
| **12 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **13 - A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to describe *the "Goals /Milestones for the remainder of the project" and the degree of confidence in completing these tasks.*** |
| **13 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |

| *MEC 495 --- Recommendations / Requirements for the SP-I --- Final Design Presentations --- Continued* | | | |
|---|---|---|---|
| **Step #** | ***Advisor(s) position regarding this step*** | ***Use a √ Mark Or Leave Blank*** | ***Description of the Recommendation / Requirement*** |
| **14 - A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to display the Gantt Chart of the project [and possibly use of Critical Path Method (CPM)].** |
| **14 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **15 - A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to:**<br>**a) Create the preliminary Group activity-based slides,**<br>**b) Assemble the slides relevant to individual member contributions,**<br>**c) Integrate the above slides to achieve the recommendations listed in items *#1 through #14*,**<br>**d) Practice the presentation to achieve a seamless transition from one to the next area, and**<br>***e) Ensures that it remains within the allocated time for this specific presentation.*** |
| **15 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **16 - A** | *Advisor(s) Concur with and Require this Step* | | **Your entire team needs to:**<br>**a) Make a mock presentation to the advisor(s) for a critique,**<br>**b) Incorporate/address the suggestions and (potential) concerns by the advisor(s), and**<br>**c) Practice the *modified presentation* to ensure that all (updated) parameters are successfully addressed and in properly in place.** |
| **16 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |
| **17 - A** | *Advisor(s) Concur with and Require this Step* | | **The team needs to realize that there would be a broad range of different audiences witnessing the presentation and should choose the proper attire!** |
| **17 - B** | *Advisor(s) have additional Requirements for this step* | | *(Describe/ List Additional Requirements Here)* |

*Appendix-G*

**Evaluation of the Progress on Senior Project (since the last presentation)**

**Mechanical Engineering *Senior Project-II***

**Peer Evaluation of the Progress on the Senior Projects**

***Wednesday, February 9th and February 16th, 2022***

Requirements:

As different teams present their progress during the winter Break, you need to assess:

1. Each Team's Effective Progress in the past 9 / 10 weeks,
2. Each Team's Chances for Successful and Timely Completion of their Project
3. As discussed for the preparations of the Progress Presentations, at the minimum, each presenting team would be addressing the following criteria. So, your evaluation would be based on progress made on these parameters:

   **A-** Progress on Completion of the different Aspects of the Design (since 9 **/**10 weeks ago),

   **B-** Progress on completion of the "Working Drawings" and their approval by "both" the advisor(s) and Supervisor Zanetti,

   **C-** Progress on obtaining/ordering the relevant materials and components,

   **D-** Progress made on the Manufacturing and Prototyping,

   **E-** What is the status of the Team's Budget and what % of it has been used up (by now), and

   **F-** Team's estimated time/week of completion along with an "updated" Gantt Chart.

4. Your Team must present a "Table reflecting on the Dates, Days, and Hours spent on Different Tasks" since your last presented.
5. To make "your team's" presentation further more effective, incorporate the following:

   **A-** Number the slides,

   **B-** Have an *Introductory Slide* to refresh the audience of the overall objectives of your specific project,

   **C-** Practice to ensure that you will remain within the allotted time.

6. Upon completion of your evaluation of all **17** Projects (including yours), you need to scan and submit (pages 2 and 3 of) it onto CANVAS. This will be counting as part of your grade in SP-II (from the collective results of your peers and the SP-Coordinator).

*Note-1: Teams on the Shaded Rows will be presenting on the first of the two sessions. The remaining teams will do so on the following week.*

*Note-2: The SP Coordinator will provide Hard Copies of pages 2 and 3 of this file for all of you in the First Session. So, don't print one.*

*Appendix-H*
**Senior Project Satisfaction Survey – Blank Form**

**SCHOOL OF ENGINEERING at THE COLLEGE OF NEW JERSEY**
**AY: 2021-22**
***SENIOR PROJECT EXPERIENCE***
**Department of Mechanical Engineering**

**Your Major:** ***Mechanical Engineering*** ←- → ***Engineering Science (with M.E. Concentration)***

Please indicate your overall satisfaction with the following attributes of senior project. Mark N/A for attributes that are not applicable or if you have no opinion.

| # | Attribute | Your Overall Satisfaction 1= Not Satisfied → 5=Very Satisfied | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Apply Knowledge of Mathematics, Science, and Engineering to Solve Challenging Engineering Problems | 1 | 2 | 3 | 4 | 5 | NA |
| 2 | Apply Knowledge from Past Coursework | 1 | 2 | 3 | 4 | 5 | NA |
| 3 | Utilize Modern Engineering Tools and Techniques to Solve Complex Engineering Problems | 1 | 2 | 3 | 4 | 5 | NA |
| 4 | Use of computational tools for analysis and optimization of design | 1 | 2 | 3 | 4 | 5 | NA |
| 5 | Analyze and Interpret Data | 1 | 2 | 3 | 4 | 5 | NA |
| 6 | Design a Component or System to Meet Desired Needs | 1 | 2 | 3 | 4 | 5 | NA |
| 7 | Build Prototypes and Working Models | 1 | 2 | 3 | 4 | 5 | NA |
| 8 | Include a Variety of Realistic Constraints, such as Economic Factors, Safety, Reliability, Aesthetics, and Social & Environmental impact | 1 | 2 | 3 | 4 | 5 | NA |
| 9 | Communication through Oral Presentations and Written Reports | 1 | 2 | 3 | 4 | 5 | NA |
| 10 | Recognize Professional and Ethical Responsibilities and Consider the Potential Adverse Effects of Engineering Solutions | 1 | 2 | 3 | 4 | 5 | NA |
| 11 | Function on a Team | 1 | 2 | 3 | 4 | 5 | NA |
| 12 | Recognize and Apply Good Practices in Project Management | 1 | 2 | 3 | 4 | 5 | NA |
| 13 | Interaction with Team Members | 1 | 2 | 3 | 4 | 5 | NA |
| 14 | Conduct Background Research | 1 | 2 | 3 | 4 | 5 | NA |
| 15 | Consider and Generate Alternative Designs | 1 | 2 | 3 | 4 | 5 | NA |
| 16 | Acquire and Apply New Knowledge and Skills as needed | 1 | 2 | 3 | 4 | 5 | NA |
| 17 | Availability and Interaction with the Senior Project Advisor | 1 | 2 | 3 | 4 | 5 | NA |
| 18 | Technical Assistance/Guidance Provided by Your Senior Project Advisor | 1 | 2 | 3 | 4 | 5 | NA |
| 19 | Process of the Formation of Teams and Availability of Projects | 1 | 2 | 3 | 4 | 5 | NA |
| 20 | Instructions and Guidelines provided by the SP-Coordinator | 1 | 2 | 3 | 4 | 5 | NA |
| 21 | Availability of the Dedicated SP Space and the Manufacturing Facilities | 1 | 2 | 3 | 4 | 5 | NA |
| 22 | Availability of the Requested Budget for Your Project | 1 | 2 | 3 | 4 | 5 | NA |
| 23 | Guidance and Assistance (as needed) in the Manufacturing of Your SP | 1 | 2 | 3 | 4 | 5 | NA |
| 24 | Your Overall Experience with Your Senior Project | 1 | 2 | 3 | 4 | 5 | NA |

***→ NOW PLEASE GO BACK AND CIRCLE THE 5 MOST IMPORTANT ATTRIBUTES LISTED ABOVE ←***