Program-Level Assessment: Annual Report

Program Name (no acronyms): Mechanical Engineering

Department: Aerospace & Mechanical Engineering

Degree or Certificate Level: BS

College/School: School of Science & Engineering

Date (Month/Year): Nov 2023

Assessment Contact:

In what year was the data upon which this report is based collected? 2022-23

In what year was the program's assessment plan most recently reviewed/updated? Fall 2023

Is this program accredited by an external program/disciplinary/specialized accrediting organization or subject to state/licensure requirements? YES – ABET accredits the engineering programs.

If yes, please share how this affects the program's assessment process (e.g., number of learning outcomes assessed, mandated exams or other assessment methods, schedule or timing of assessment, etc.): The HLC learning outcomes are derived from the ABET outcomes and the assessment process is similar to that of ABET.

1. Student Learning Outcomes

Which of the program's student learning outcomes were assessed in this annual assessment cycle? (Please provide the complete list of the program's learning outcome statements and **bold** the SLOs assessed in this cycle.)

Students should be able to

1. **Identify, formulate, and solve complex engineering problems in the mechanical domain by applying principles of engineering, science, and mathematics.**
2. Apply engineering methods to design mechanical and thermal systems that meet specified mission needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. **Communicate effectively with a range of audiences.**
4. 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. **Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.**
6. Develop and conduct appropriate experimentation in the mechanical engineering domain, analyze and interpret data, and use engineering judgment to draw conclusions.
7. **Acquire and apply new knowledge applicable to a mechanical engineering career using appropriate learning strategies.**

2. Assessment Methods: Artifacts of Student Learning

Which artifacts of student learning were used to determine if students achieved the outcome(s)? Please describe the artifacts in detail, identify the course(s) in which they were collected, and if they are from program majors/graduates and/or other students. Clarify if any such courses were offered a) online, b) at the Madrid campus, or c) at any other off-campus location.

The artifacts reviewed for each outcome are listed here and provided in further detail in the attached documents, including prompt examples.
Outcome 1:
ESCI/MENG 2150 Dynamics – A final exam problem on energy/work/kinematics

ESCI/MENG 3200 Fluid Dynamics – An exam problem which in the fall was a two-dimensional conservation, in spring was a dimensionless analysis, Buckingham Pi problem
MENG 4300 Heat Transfer –An exam problem
MENG 2150 Dynamics and MENG 3200 Fluid Dynamics are taught in Madrid. These courses have other program students (Aerospace and Civil Engineering primarily), but results are sorted by degree program. MENG 4300 has both aerospace and mechanical engineering students, but results are sorted by program.

Outcome 3:
MENG 1000 Design Thinking – Project report and presentation
ESCI/MENG 3201 Fluids Lab – Formal lab report written individually for the Flat Plate Boundary Layer Lab
MENG 4014 Senior Design II – Senior team design presentation and report
Design Thinking is taught in Madrid. Fluids Lab has other program students (Aerospace and Civil Engineering primarily), but results are sorted by degree program. MENG 1000 has a few non-mechanical engineering students (<10%) pursuing minor in Mechanical Engineering. MENG 4004 rarely have non-mechanical engineering students.

Outcome 5:
ESCI/SE 1700 Engineering Fundamentals – Team project performance based on instructor observations, team questionnaire, and final project report/presentation
ESCI/MENG 3101 Solid Mechanics Lab – Team questionnaire
MENG 4004 Senior Design I – Assignments and design report
Engineering Fundamentals is taught in Madrid. Engineering Fundamentals includes students in all engineering majors as well as other majors, but results are sorted by degree program. Solid Mechanics Lab has Aerospace and Civil engineering students, and the results are not sorted by major. Senior Design rarely has non-mechanical engineering students.

Outcome 7:
ESCI/SE 1700 Engineering Fundamentals – Development and explanation of a bibliography related to the class project
MENG 2000 Foundation to Engineering Design - Design project
MENG 2450 Engineering Experimentation – A new course and the review has not happened yet.
Engineering Fundamentals is taught in Madrid. Foundation to Engineering Design, Engineering Experimentation, and Senior Design rarely have non-Aerospace students.

3. Assessment Methods: Evaluation Process

What process was used to evaluate the artifacts of student learning, and by whom? Please identify the tools(s) (e.g., a rubric) used in the process and **include them in/with this report document** (please do not just refer to the assessment plan).

Outcome 1: All artifacts are evaluated by the instructor. Exam questions and assignments may be reviewed by a grader/teaching assistant before instructor review. Methodology/rubrics for assessed artifacts in this cycle are provided in the additional materials.

Outcome 3: All artifacts are evaluated by the instructor. MENG 1000 may also use a panel of graders/teaching assistants to evaluate presentations. Lab reports are generally graded by a grader/teaching assistant before instructor review. Methodology/rubrics for assessed artifacts in this cycle are provided in the additional materials.

Outcome 5: Student questionnaires are student evaluations of their and their team’s performance. All other artifacts are evaluated by the instructor. Graders may assist in the assessment in ESCI/SE 1700. Methodology/rubrics for assessed artifacts in this cycle are provided in the additional materials.

Outcome 7: All artifacts are evaluated by the instructor. Methodology/rubrics for assessed artifacts in this cycle are provided in the additional materials.

For all artifacts, the summary of the course assessment is presented to the department when the outcome is collectively reviewed and can undergo further review at that time.

4. Data/Results

What were the results of the assessment of the learning outcome(s)? Please be specific. Does achievement differ by teaching modality (e.g., online vs. face-to-face) or on-ground location (e.g., STL campus, Madrid campus, other off-campus site)?

Outcome 1:
MENG 2150 - Across two semesters, 17 of 24 mechanical engineering students at least met expectations and of those 2 exceeded expectations. This was just at the target level of 70% at least meeting expectations. Those who did not meet expectations generally had difficulties setting up the proper equations and the subsequent mathematics.
MENG 3200 – In the semester reviewed, 7 of 19 mechanical engineering students exceeded expectations, 6 met expectations, and 6 did not meet expectations. This was just below (68%) the desired level of 70% met/exceed expectations. Primary issues were proper equation set up and mathematical errors. The math level was more at a high school level than college (trig, algebra), so the number of errors of this type were concerning. Possibly connected to COVID issues or time pressures.
MENG 4400 - One semester, 6 of 9 mechanical engineering students at least met expectations of at least a 70% class grade, with 3 identified as exceeding expectations. This is just below (67%) the goal of 70% of students at least meeting expectations. Choosing the proper equation set up and vector math errors were the primary issues along with time constraints. Note that the number of students reviewed is less than 10 to make any strong conclusions.

Outcome 3:
MENG 1000 – Based on data from Spring 2022 and Spring 2023, all 20 teams consisting of 77 students met or exceeded expectations and 31 students exceeded expectations. Madrid across 2021 and 2022 saw seven of nine students meet or exceed expectations with three of the four mechanical engineering students doing so based on project portfolio development and a presentation.
MENG 3201 – Based on data from one section in Fall 2022, three of 14 students did not meet expectations and 79% of students did, exceeding the goal of 70% meeting or exceeding expectations. The greatest weaknesses were in the ability to properly organize the information in a lab report and to communicate technical concepts in figures and written communication.
MENG 4014 – 34 of 37 students in six teams met or exceeded the class communication participation requirement while all teams and students met the presentation and written report expectations. The students that did not meet the class participation expectations were all in a single group, in which the remaining students did additional work to compensate.

Outcome 5:
AENG 3101 – All students met expectations, but data is not divided by major
MENG 4004 – 34 of 37 students in six teams met or exceeded the teamwork/management expectations, akin to the results in Outcome 3. One student missed classes due to SLU athletic events and was hampered in meeting this expectation. Unexcused lack of participation by the two other students resulted in their failing to meet expectations.

Outcome 7:
ESCI 1700 – 20 of 22 of graded mechanical engineering students met expectations
MENG 2000 – 32 of 34 students in 15 total teams met or exceeded expectations based on a design project. Lack of effort was the main issue with the team that did not meet expectations. In the Madrid section, two students exceeded and three meet expectations out of 5 on a bridge building project.

5. Findings: Interpretations & Conclusions

What have you learned from these results? What does the data tell you? Address both a) learning gaps and possible curricular or pedagogical remedies, and b) strengths of curriculum and pedagogy.

Outcome 1

- Students had trouble with pre-req material (Math & Physics) and were not well-prepared. These concepts were retaught in the dynamics and fluid dynamics courses. This could be because of Covid.

Outcome 3
- Student overall written and oral communication skills (as opposed to specifically technical) have generally met or exceeded expectations.
- Students need improved technical writing skills as opposed to general writing skills – including incorporation of equations/tables/data/plots.

Outcome 5
- Most design teams (summative/achieved assessment) appear to at least meet expectations.
- Currently, we don't formally introduce team management skills in most of the curriculum until senior design even though there are many team activities.

Outcome 7
- Students generally demonstrate appropriate library and bibliography skills.
- Senior design teams naturally develop new knowledge to complete their projects.

6. Closing the Loop: Dissemination and Use of Current Assessment Findings

A. When and how did your program faculty share and discuss the results and findings from this cycle of assessment?

Faculty assessed outcomes 1 and 3 in April/May 2023 and outcomes 5 and 7 in Nov 2023.
The faculty provided assessment data including review sheets and artifacts. Then, the department faculty members reviewed the assessment materials in multiple meeting to identify strengths, weaknesses, and propose changes to the curriculum/courses/assessment methods.

B. How specifically have you decided to use these findings to improve teaching and learning in your program? For example, perhaps you've initiated one or more of the following:

Changes to the Curriculum or Pedagogies	• Course content • Teaching techniques • Improvements in technology • Prerequisites	• Course sequence • New courses • Deletion of courses • Changes in frequency or scheduling of course offerings
Changes to the Assessment Plan	• Student learning outcomes • Artifacts of student learning • Evaluation process	• Evaluation tools (e.g., rubrics) • Data collection methods • Frequency of data collection

Please describe the actions you are taking as a result of these findings.

Outcome 1
- Students had trouble with pre-req material (Math & Physics) and were not well-prepared. These concepts were retaught in the dynamics and fluid dynamics courses. This could be because of Covid.
- Action plan – We are monitoring student performance in Dynamics to see if issues continue with increased sample size. If necessary, we will coordinate appropriate action in collaboration with the math and physics departments.

Outcome 3
- Students need improved technical writing skills as opposed to general writing skills – including incorporation of equations/tables/data/plots.
- Action plan – We are in the process of developing common definitions for report format, figures, equations, calculations, and sections to be used generally across the curriculum.

Outcome 5
- Currently, we don't formally introduce team management skills.
- Action plan – We are in the process of creating first-year team building exercises in collaboration with ROTC.

If no changes are being made, please explain why.

Outcome 7 is awaiting approval for Cura Personalis 3 as part of senior design, will evaluate potential changes after that approval.

7. Closing the Loop: Review of Previous Assessment Findings and Changes

A. What is at least one change your program has implemented in recent years **as a result of previous assessment data**?

A common first year Ignite course (SE 1700) was introduced in Fall 2022. Apart from satisfying the core requirement, the course provides an opportunity to work in interdisciplinary teams doing interdisciplinary work on a complex problem. The course was introduced based on the previous assessment data to effectively address outcomes 2 and 5.

B. How has the change/have these changes identified in 7A been assessed?

They were reviewed by the faculty during Summer 2023.

C. What were the findings of the assessment?

Engineering Methods – The design-build-test cycle is an integral part of engineering practice. The build/test portions were not sufficiently implemented. It resulted in a lack student engagement and understanding.

D. How do you plan to (continue to) use this information moving forward?

All sections of the project now include a hands-on activity with associated engineering analysis.

IMPORTANT: Please submit any assessment tools (e.g., artifact prompts, rubrics) with this report as separate attachments or copied and pasted/appended into this Word document. Please do not just refer to the assessment plan; the report should serve as a stand-alone document. Thank you.

Additional course materials are provided by outcome, with each outcome headed by a summary page developed in the department review followed by course-specific information.

AEME ABET Assessment Review Form

This form is a summary of the collective departmental review of learning outcome assessment, to be used to record review group thoughts about assessment materials collected.

Program (AE or ME): ME   Date materials reviewed: 04/24/2023, 05/10/2023

Criterion reviewed (circle one): 1 2 3 4 5 6 7

an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

Semester(s) reviewed: Fall 2022 (primarily)

Reviewers: Alexander, Condoor, Gururajan, Jayaram, LeBeau, Lei, Marmolejo, McQuilling, Swartwout

Courses and instruments:

Course	Semester	Description (ind/Grp)	Level	Math	Sci	Cplx
MENG 2150	AE (S) ME (F)	Final Exam problem on energy/work/kinematics in a system (Individual)	Early Formative	N	N	N
MENG 3200	AE (S) ME (F)	Ind Exam Problem 2D C mass/momentum, dimensionless analysis	Middle Formative	N	N	N
MENG 4300	ME (S)	Examination Problem: Combined Conduction and Natural Convection (Individual)	Late Summative	N	?	?

Strengths and weaknesses:

Mechanical students had 14 of 19 students meet or exceed expectations in MENG 2150 Dynamics and 13 or 19 do so in MENG 3200 Fluid Dynamics. These scores are around the desired 70% meets or better standard, with Dynamics just above and Fluid Dynamics just below.

General observations on student preparedness including math and science knowledge retained from the first year of college. Several faculty found the need to re-teach concepts that are supposed to have been learned in pre-requisite courses.

Recommendations and proposed actions:

Develop specific assessment instruments for MENG 4300 Heat Transfer (Marmolejo) (This was done in the spring semester)

Monitor ME student performance in Fluid Dynamics during spring semester to see if issues continue with increased sample size.

Review pre-requisite requirements, increase documentation of expectations from pre-requisite courses including physics, math courses.

Other comments: This was the first review of this outcome under the newly revised assessment plan of August 2022.

Learning Outcome: **1 (Solve Problems using SEM)** 2 (Design in Global Context) 3 (Effective Communication)

[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)

7 (Lifelong Learning)

Course: ESCI 2150 (Dynamics) (Fall 2022)

Location in Program: Early Middle End

Method: *As part of the final exam in the course, students are tasked with applying energy methods (work, potential energy, kinetic energy) to calculate the motion of a wheel*

Rubric: *To satisfy the outcome, students must identify the energy balance equation and its components, apply boundary conditions and solve for the unknown parameter. They must also identify geometric constraints (the no-slip condition) and use them to eliminate unknowns. The rubric is attached.*

Desired result: 70% of students will meet expectations, which is defined as earning at least 11 of 15 points on the problem. To earn that many points, the students must apply the correct equations and eliminate most of the unknowns

Student performance: 74% of mechanical engineering students met expectations (14 of 19)

Observations: Nearly half of the students missed 0 or 1 point; those that missed 1 point either had an arithmetic error or substituted the incorrect value for mass moment of inertia.

Of the five students who did not meet expectations, two were close (10 out of 15) but had two conceptual errors in the basic equation of motion (either removed key elements from the equation or added extra terms). Two more demonstrated no work other than parroting the base energy balance equation. The remaining student made three conceptual errors (incorrectly applied the work equation, incorrectly defined potential energy, solved for the wrong parameter).

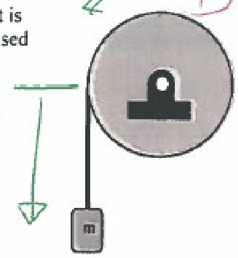
Program Assessment: *Is this an outlier (small sample size) or a cause for concern?*

Action: *[Recommended responses]*

10) [15 pts] Déjà vu, All Over Again. A block (mass = 8.163 kg) is attached to a rope that is wound around a solid cylinder (mass 12.117 kg, radius 1.25 meters). The block is released from rest.

Calculate the angular velocity of the cylinder after the block has dropped 11.25 meters, **using energy methods.**

ω 1



S_B 1

5

$$\underbrace{T_1}_{0} + \underbrace{V_1}_{S=0} + \underbrace{W_{1\to2}}_{\text{NO EXTERNAL WORK}} = T_2 + V_2$$

REST 1 2

Position 1: Rest $S_B = 0$

Position 2: $S_B = 11.25\,m$

2

$$0 = \frac{1}{2} m_B V_B^2 + \frac{1}{2} I\omega^2 - m_B g S_B$$

1 NO SLIP: $V_B = R\omega$ $\quad I = \frac{1}{2} m_W R^2$ 1

Combine & Solve

1

$$\frac{2 m_B g S_B}{m_B R^2 + \frac{1}{2} m_W R^2} = \omega^2 \qquad \boxed{\omega = 9\ \text{rad/s}}$$

Learning Outcome: **1 (Solve Problems using SEM)** 2 (Design in Global Context) 3 (Effective Communication)

[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)

7 (Lifelong Learning)

Course: ESCI 2150 (Dynamics) (Spring 2023)

Location in Program: Early **Middle** End

Learning Outcome 1: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

Instrument: 2D Kinematics Rigid Body Examination Problem

Methodology: Exam problem (included) is graded by instructor. Assessment is based on performance solving the problem and the rubric. The instructor can more precisely define the interpretation of rubric for the particular problem.

Rubric: See rubric below.

Desired result: 70% of students scoring Meets or Above Expectations

Students assessed: This assessment focuses on the 5 students who are majoring in mechanical engineering out of the total class size of 40 students. The remaining students consist of 20 majoring in aerospace engineering and 15 majoring in civil engineering.

Student performance: Out of the 5 mechanical engineering students, the performance assessment revealed that 2 students were classified as "Above Expectations," 1 students as "Meets Expectations," and 2 students as "Below Expectations."

Observations: Common errors were identified in the kinematic diagram among the mechanical engineering students. These errors primarily involved incorrect setup of the relative position vector $r_{B/A}$ or inaccurate equations for absolute velocity and acceleration. Additionally, some students made mistakes when solving cross products and improperly separating the *i* and *j* components in the final acceleration equation.

Assessment: 60% of the Mechanical engineering students met or exceeded expectations.

Proposed Action: Based on the assessment results, it is evident that the Mechanical engineering program is not meeting expectations in the areas evaluated. To address this issue, it is recommended to strengthen the students' understanding of basic kinematic concepts in the preceding courses. This can also be achieved by incorporating hands-on exercises and experiments during this course to enhance their comprehension of fundamental concepts. Furthermore, it is advisable to monitor the performance of future classes in subsequent semesters to assess whether the implemented measures have positively impacted the students' learning outcomes. Continuous evaluation and improvement will be crucial in ensuring the program meets the desired standards in the long term.
The current artifact primarily focuses on cross products, trigonometry, and linear algebra, resulting in a predetermined outcome. Exploring alternative assessment methods that encompass a wider range of skills will provide a more comprehensive evaluation of students' abilities.

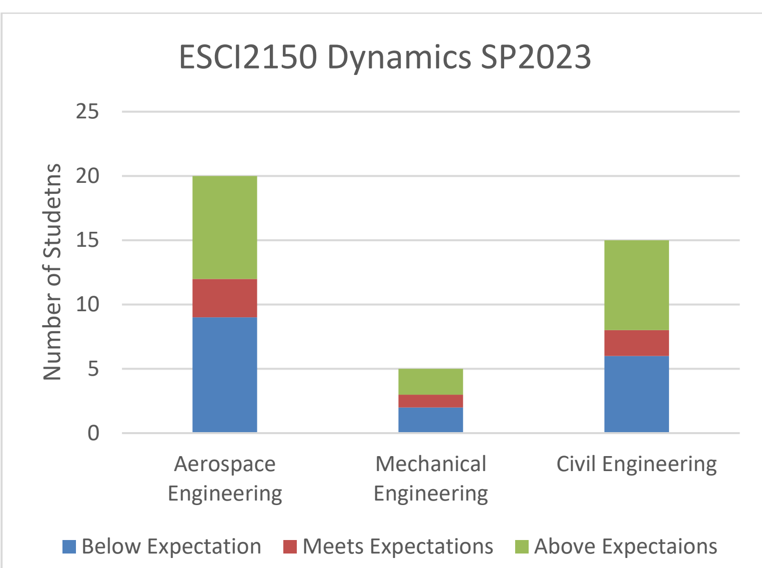
Indicator	Below Expectations	Meets Expectations	Above Expectations
Ability to analyze and solve two-dimensional rigid body kinematic problems involving rotation around an external instantaneous center of zero velocity.	Student fails to solve the problem due to significantly improper procedures, incorrect equations, incomplete work, and/or significant mathematical errors.	Student uses mostly proper procedures to formulate and solve the resulting governing equation with at most a few errors.	Student uses proper procedures to formulate and solve the governing equations with minimal errors.

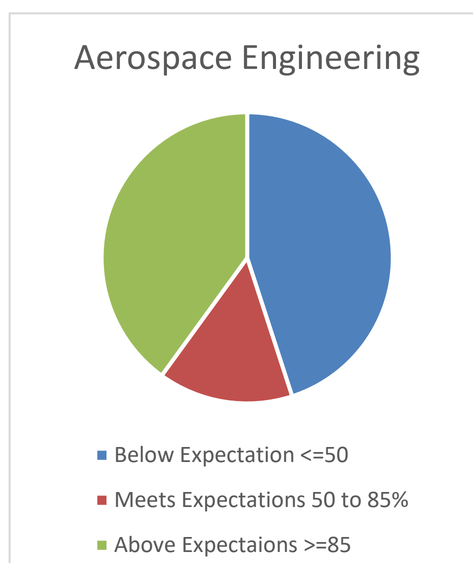
Proficiency in this area includes:

1. Demonstrating the ability to identify and understand the key components of a problem, including knowns, unknowns, givens, and constants.
2. Kinematic Diagram: Creating clear and accurate diagrams that depict the system, including relevant bodies, rotational axes, and the external instantaneous center.
3. Velocity Analysis: Determining the instantaneous velocities of different points or bodies within the system, considering both linear and angular velocities. This requires understanding the concept of an external instantaneous center of zero velocity.
4. Acceleration Analysis: Analyzing the accelerations of various points or bodies in the system, accounting for both linear and angular accelerations. This involves applying relevant principles, such as centripetal acceleration and tangential acceleration.
5. Equation Formulation: Developing appropriate equations that establish relationships between known and unknown quantities, incorporating the principles of rotational motion and the concept of the external instantaneous center of zero velocity.
6. Problem Solving: Applying mathematical techniques, such as trigonometry and vector algebra, to solve the formulated equations and obtain solutions for the desired quantities.

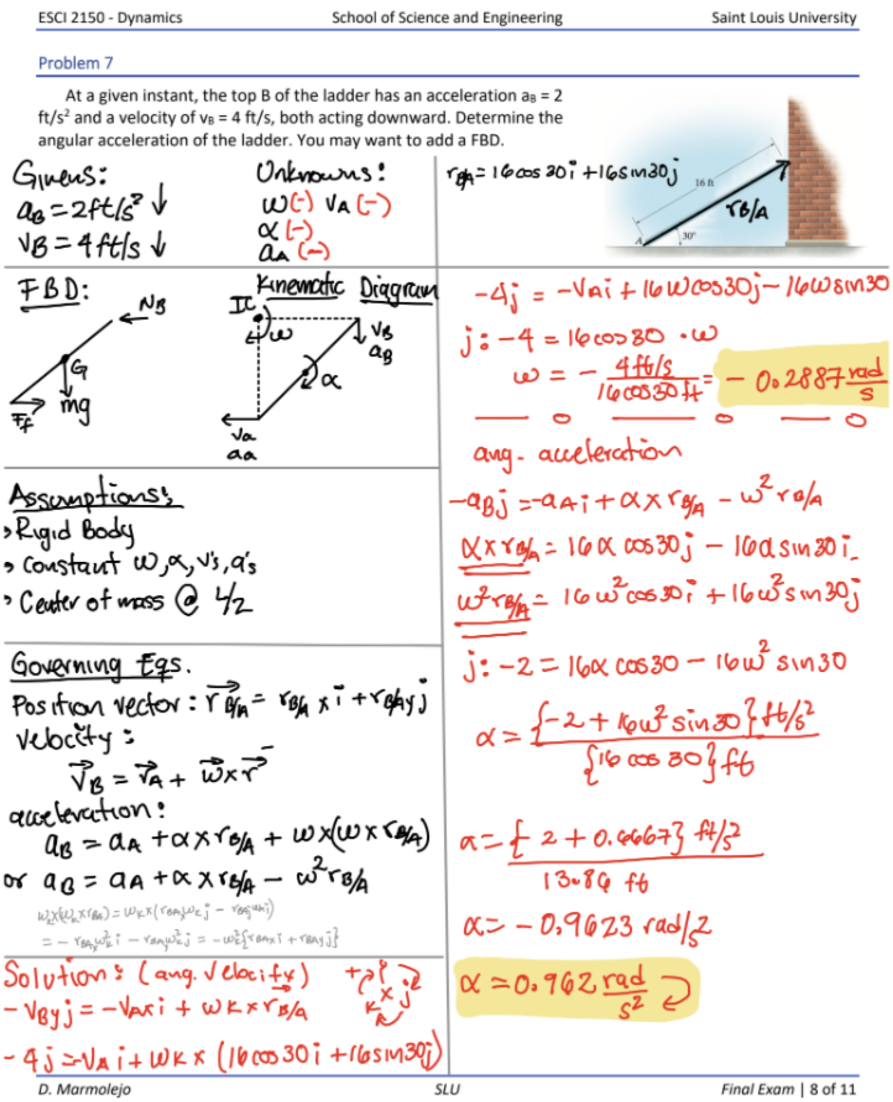
This skill set enables engineers to effectively analyze and solve complex motion problems encountered in various fields, including mechanical engineering, robotics, and dynamics. It plays a vital role in designing mechanisms, optimizing motion control systems, and ensuring the desired performance of rotational components.

In the assessment, a score below 50% was classified as automatically falling into the "Below Expectations" category. Conversely, a score above 85% was deemed automatically as "Above Expectations." For scores falling between these thresholds, an assessment of the nature of errors and how they aligned with the established rubric was conducted, with the possibility of categorizing them into any of the three categories: "Above Expectations," "Meets Expectations," or "Below Expectations."





This approach provided a clear framework for evaluating student performance and determining their level of achievement based on the established criteria. It allowed for a comprehensive assessment that considered both numerical scores and qualitative analysis, taking into account the specific errors made and their alignment with the performance expectations outlined in the rubric.



ESCI 2150 - Dynamics | School of Science and Engineering | Saint Louis University

Problem 7

At a given instant, the top B of the ladder has an acceleration $a_B = 2$ ft/s^2 and a velocity of $v_B = 4$ ft/s, both acting downward. Determine the angular acceleration of the ladder. You may want to add a FBD.

Givens:
$a_B = 2 ft/s^2 \downarrow$
$v_B = 4 ft/s \downarrow$

Unknowns:
$\omega(-)$ $v_A(-)$
$\alpha(-)$
$a_A(-)$

$r_{B/A} = 16\cos 30 \hat{i} + 16\sin 30 \hat{j}$

FBD:

Kinematic Diagram

$-4j = -V_a i + 16\omega\cos30 j - 16\omega\sin30$

$j: -4 = 16\cos 30 \cdot \omega$

$\omega = -\frac{4 ft/s}{16\cos30 ft} = -0.2887 \frac{rad}{s}$

ang. acceleration

$-a_B j = -a_A i + \alpha \times r_{B/A} - \omega^2 r_{B/A}$

$\alpha \times r_{B/A} = 16\alpha\cos30 j - 16\alpha\sin30 i$

$\omega^2 r_{B/A} = 16\omega^2\cos30 i + 16\omega^2\sin30 j$

$j: -2 = 16\alpha\cos30 - 16\omega^2\sin30$

$\alpha = \frac{\{-2 + 16\omega^2\sin30\} ft/s^2}{\{16\cos30\} ft}$

$\alpha = \frac{\{2 + 0.6667\} ft/s^2}{13.86 ft}$

$\alpha = -0.9623\ rad/s^2$

$\alpha = 0.962 \frac{rad}{s^2}$

Assumptions:
- Rigid Body
- Constant $\omega, \alpha, v's, a's$
- Center of mass @ L/2

Governing Eqs.
Position vector: $\vec{r}_{B/A} = r_{B/A\,x}\hat{i} + r_{B/A\,y}\hat{j}$
velocity:
$\vec{v}_B = \vec{v}_A + \vec{\omega} \times \vec{r}$
acceleration:
$a_B = a_A + \alpha \times r_{B/A} + \omega \times (\omega \times r_{B/A})$
or $a_B = a_A + \alpha \times r_{B/A} - \omega^2 r_{B/A}$
$\omega_k \times (\omega_k \times r_{B/A}) = \omega_k \times (r_{BAx}\omega_k j - r_{BAy}\omega_k i)$
$= -r_{BAx}\omega_k^2 i - r_{BAy}\omega_k^2 j = -\omega_k^2\{r_{BAx} i + r_{BAy} j\}$

Solution: (ang. velocity)
$-V_{By} j = -V_{Ax} i + \omega k \times r_{B/A}$
$-4j = -V_A i + \omega k \times (16\cos30 i + 16\sin30 j)$

D. Marmolejo | SLU | Final Exam | 8 of 11

Learning Outcome:	1 (Solve Problems using SEM)	2 (Design in Global Context)	3 (Effective Communication)
[select 1]	4 (Ethics in Global Context)	5 (Functional Teamwork)	6 (Experiment and Draw Conclusions)
	7 (Lifelong Learning)		

Course: ESCI 3200 (Fluid Dynamics) (Fall 2022)

Location in Program: Early **Middle** End

Learning Outcome 1: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

Instrument: 2D CV Conservation of Mass/Momentum exam problem

Methodology: Exam problem (included) is graded by instructor. Assessment is based on performance solving the problem and the rubric. The instructor can more precisely define the interpretation of rubric for the particular problem.

Rubric: See rubric below.

Desired result: 70% of students scoring Meets or Above Expectations

Students assessed: The class consisted of 40 students, of whom 19 were majoring in mechanical engineering, 11 in aerospace engineering, 9 in civil engineering, and 1 in engineering physics. This assessment is based on 19 mechanical engineering students.

Student performance: The Mechanical Engineering students had 7 students in Above Expectations, 6 in Meets Expectations, and 6 in Below Expectations.

Observations: Common errors were a failure to include sines and cosines for the sloped pipe, sign errors in momentum flux terms. Multiple students in Meets Expectations appeared to understand how to construct the equations and potentially solve them but ran out of time or the like.

Assessment: 68% of the mechanical engineering students met or exceeded expectations.

Proposed Action: Results indicate that the ME program is marginally meeting expectations here. While this does not appear to require action at the moment, it should continue to be monitored.

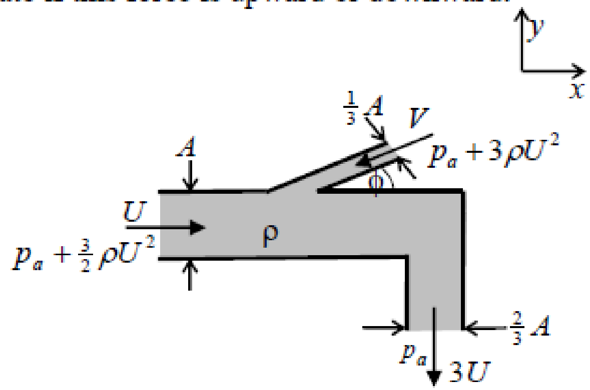
Consideration should also be given for a different assessment artifact that better evaluates math, science, and complex problem solving – the math here is primarily dot products, trigonometry, and algebra, and the outcome is of course foreordained.

Indicator	Below Expectations	Meets Expectations	Above Expectations
Ability to formulate and solve a two-dimensional control volume mass-momentum conservation problem.	Student fails to solve the problem due to significantly improper procedures, incorrect equations, incomplete work, and/or significant mathematical errors.	Student uses mostly proper procedures to formulate and solve the resulting governing equation with at most a few errors.	Student uses proper procedures to formulate and solve the governing equations with minimal errors.

A score below 60% was treated as automatically Below Expectations, Above 87% was considered automatically Above Expectations. Between was an assessment of the nature of the errors and how it fit in the rubric above, with all three categories possible.

1. A liquid flows into a system from two pipes and out one pipe as illustrated. Assume the flow is steady, horizontal (no body forces), incompressible, strongly rotational, and inviscid. All pipe cross-sectional areas are given in terms of A and have uniform cross-sectional properties. **(32%)**

Given this information, determine the value of ϕ such that the net horizontal force on the pipe goes to zero. What is the net vertical force that the fluid is exerting on the pipe in this configuration in terms of ρ, U, and H? Clearly state if this force is upward or downward.



$$Mass: \quad -\rho UA + \rho(3U)\tfrac{2}{3}A - \rho V(\tfrac{1}{3}A) = 0$$

$$\Rightarrow \quad \tfrac{1}{3}V = -U + 2U = U \quad V = 3U$$

$x-momentum:$

$$-\rho U^2 A + \rho V^2 \cos\varphi(\tfrac{1}{3}A) = \tfrac{3}{2}\rho U^2 H^2 - 3\rho U^2(\tfrac{1}{3}A)\cos\varphi$$

$$\Rightarrow \quad -U^2 + \tfrac{1}{3}V^2 \cos\varphi = \tfrac{3}{2}U^2 - U^2\cos\varphi$$

$$\Rightarrow \quad \cos\varphi\left[3U^2 + U^2\right] = \tfrac{3}{2}U^2 + U^2$$

$$\Rightarrow \quad 4U^2\cos\varphi = \tfrac{5}{2}U^2 \quad \Rightarrow \quad \cos\varphi = \frac{1}{4}\frac{5}{2} = \frac{5}{8}$$

$$\Rightarrow \quad \varphi = \cos^{-1}\left(\frac{5}{8}\right) = 51.3^\circ$$

$y-momentum:$

$$-\rho(3U)^2\tfrac{2}{3}A + \rho V^2 \sin\varphi(\tfrac{1}{3}A) = -3\rho U^2(\tfrac{1}{3}A)\sin\varphi - F_y$$

$$\Rightarrow \quad -6\rho U^2 A + 3\rho U^2 A\sin\varphi = -\rho U^2 A\sin\varphi - F_y$$

$$\sin\varphi = \sqrt{1-\cos^2\varphi} = \sqrt{1-\frac{25}{64}} = \sqrt{\frac{29}{64}} = 0.7806$$

$$\Rightarrow \quad F_y = \rho A\left\{\sin\varphi\left[-3U^2 - U^2\right] + 6U^2\right\} = \rho U^2 A\left\{-3.1225 + 6\right\} = 2.8775\rho U^2 H^2$$

Learning Outcome: **1 (Solve Problems using SEM)** 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: MENG 4300 (Heat Transfer)

Location in Program: Early **Middle** **End**

An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

Instrument: Examination Problem: Combined Conduction and Natural Convection

Methodology: The exam problem (included) is graded by the instructor. Assessment is based on the performance in solving the problem and the rubric. The instructor can provide a more precise interpretation of the rubric for this specific problem.

Rubric: See rubric below.

Desired result: Achieve a minimum of 70% of students scoring "Meets" or "Above Expectations."

Students assessed: This assessment focuses on the 9 students majoring in mechanical engineering out of a total class size of 28 students. The remaining students were majoring in aerospace engineering.

Student performance: Among the 9 mechanical engineering students, the performance assessment revealed that 3 students exceeded expectations, 3 students met expectations, and 3 students fell below expectations."

Observations: The current assessment predominantly centers on solving ordinary differential equations for the conduction problem and analyzing the solution of the convection part.

Common errors were identified, primarily related to equation selection. One student had difficulty accurately identifying the necessary boundary conditions and the appropriate ordinary differential equation (ODE), specifically for the conduction component of the problem. Another student selected an incorrect equation, mistakenly choosing the Raleigh number for the natural convection part of the problem. Additionally, there were instances of minor math manipulation errors involving variables, including algebraic mistakes. Furthermore, a few students made calculation errors, while others chose not to attempt solving the problem altogether. Notably, the three students who did not meet expectations faced challenges in completing the problem, which can be partly attributed to either time constraints or a limited understanding of the problem's complexity. It's important to emphasize that this problem constitutes a portion of their final exam.

Assessment: 66% of the mechanical engineering students met or exceeded expectations.

Proposed Action: Based on the assessment results, it's clear that the mechanical engineering program is on the verge of meeting expectations in the evaluated areas. To achieve this goal, a few key actions are proposed:

Firstly, consider redesigning this assessment as a stand-alone exam or quiz, allowing students ample time to complete the problem. This adjustment acknowledges the complexity of the assessment and ensures students have the necessary time to demonstrate their understanding.
Secondly, allocating more time for and providing additional practice problems with combined elements (conduction-convection-radiation) is essential. This can be achieved through the inclusion of hands-on exercises, experiments, or integrating Matlab usage into homework problems, as the nature of these problem solutions can be intricate.
Moreover, a continuous evaluation of student performance and ongoing improvement efforts will be crucial in maintaining and elevating the program to meet the desired standards in the long term.
Additionally, considering a tracking system to gauge students' understanding of fundamental concepts from previous thermal-related courses could provide timely support to those struggling with basic concepts. This proactive approach aims to address foundational knowledge gaps and facilitate overall student success.

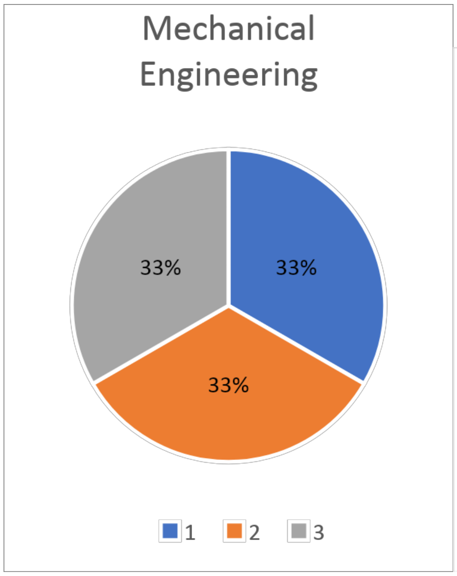
Indicator	Below Expectations	Meets Expectations	Above Expectations
Ability to analyze and solve combined heat transfer problems where conduction-convection are present.	Student fails to solve the problem due to significantly improper procedures, incorrect equations, incomplete work, and/or significant mathematical errors.	Student uses mostly proper procedures to formulate and solve the resulting governing equation with at most a few errors.	Student uses proper procedures to formulate and solve the governing equations within minimal errors.

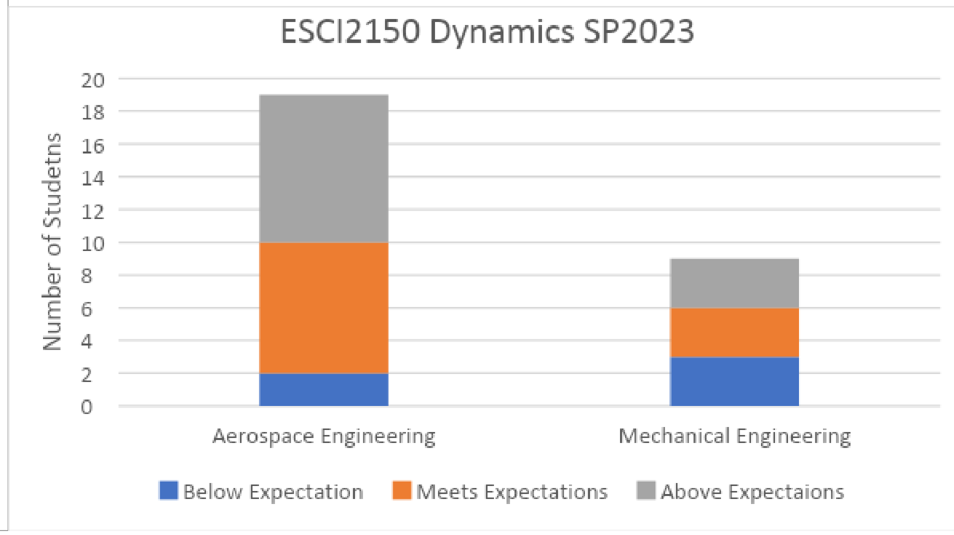
Proficiency in this area includes:

1. Demonstrating the ability to identify and understand the key components of a problem, including knowns, unknowns, given values, and constants.
2. Creating clear and accurate diagrams that depict the system, including variables, constants, the direction of heat flow, and boundary conditions.
3. Conduction: Determining the boundary conditions, ordinary differential equation (ODE), and the correct strategy to solve the differential equation.
4. Natural Convection: Determining the type of convection problem that needs to be solved at the solid-gas interface and finding the best solution strategy for the convection problem. Select the correct equations for the Raleigh and Nusselt numbers.
5. General problem solving: Applying the correct mathematical techniques, solving differential equations, and using algebra.

This skill set enables engineers to effectively analyze and solve complex motion problems encountered in various fields, including thermal engineering, thermal design, and thermodynamics.

In the assessment, a score below 50% was automatically classified as "Below Expectations," while a score above 85% was automatically categorized as "Above Expectations." For scores falling between these thresholds, an assessment of the nature of errors and how they aligned with the established rubric was conducted, with the possibility of categorizing them into any of the three categories: "Above Expectations," "Meets Expectations," or "Below Expectations."





This approach provided a clear framework for evaluating student performance and determining their level of achievement based on the established criteria. It allowed for a comprehensive assessment that considered both numerical scores and qualitative analysis, taking into account the specific errors made and their alignment with the performance expectations outlined in the rubric.

Problem 8

The air temperature inside a wood-fired pizza oven is 450°C. Determine the temperature of the oven wall, at x = 20 cm, when the wall temperature at $x = t$, Ts, is 350°C. Assume natural convection between the internal wall and hot air. Neglect heat transfer by radiation. Consider the walls of the oven as vertical brick walls of 250 mm thickness and 50 cm tall (k_{brick} = 0.75 W/m^2·K.) *Hint: you need to solve an ODE.

k = .75 w/m²

For air at 400 C

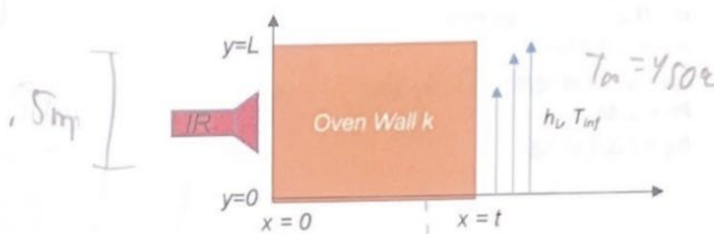
k = 0.05015 W/mK

ρ = 0.5243 kg/m3

cp = 1069 kJ/kgC

Pr = 0.6948

ν = 6.219 x 10^{-5} m^2/s



AEME ABET Assessment Review Form

This form is a summary of the collective departmental review of learning outcome assessment, to be used to record review group thoughts about assessment materials collected.

Program (AE or ME): ME Date materials reviewed: 05/10/2023

Criterion reviewed (circle one): 1 2 **3** 4 5 6 7

an ability to communicate effectively with a range of audiences

Semester(s) reviewed: Fall 2022 (primarily)

Reviewers: Alexander, Condoor, Gururajan, Jayaram, LeBeau, Lei, Marmolejo, McQuilling, Swartwout

Courses and instruments:

Course	Semester	Description (ind/Grp)	Level	Type	Audience
MENG 1000	ME (S)	Project presentation and report, small teams	Early Formative	Oral, Written	
MENG 3201/MENG 3111	ME (F) AE (S); ME (S), AE (F)	Formal Lab Report, individual	Middle Formative	Written	Technical
MENG 4014	ME (S)	Final Presentation (group), Final Report (group)	Late Summative	Oral, Written	Professional, Technical

Strengths and weaknesses:

Students need improved technical writing skills as opposed to general writing skills – including incorporation of equations/tables/data/plots.

Need to ensure that a variety of formats and audiences are covered as well individual versus group assignments and assessments.

Student overall written and oral communication skills (as opposed to specifically technical) have generally met or exceeded expectations.

Recommendations and proposed actions:

Develop common definitions for report format, figures, equations, calculations, sections, and the like to be used generally across the curriculum (Prof. Gururajan and McQuilling).

Develop proposal to integrate Core Intensive Writing attribute into MENG 4014 in conjunction with ABET outcomes (Alexander, Condoor).

Continue to encourage the development of diverse communication instruments

Other comments:

This was the first review of this outcome under the newly revised assessment plan of August 2022.

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) **3 (Effective Communication)**

[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)

7 (Lifelong Learning)

Course: MENG 1000 (Design Thinking) (spring 2022)

Location in Program: **Early** Middle End

Method: A project was assigned to the class and used to demonstrate written and oral communication skills.

Rubric: A panel of judges evaluated the project report and technical presentation. For the report, three TAs and the instructor evaluated the outcome. Three faculty members and three TAs reviewed the presentation.

Desired result: 80% of students will meet expectations

Student performance: 100% of the students (31 out of 31) met expectations. 16 students (52% of students far exceed expectations – 48% exceed expectations)

Observations:

Program Assessment: All Student teams did well in delivering their projects' written reports. The student presentation skills were good. Judges' felt that the visual elements can be improved.

Action: Incorporate a module on presentation skills.

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) **3 (Effective Communication)**
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: MENG 1000 (Design Thinking) (spring 2023)

Location in Program: **Early** Middle End

Method: A project was assigned to the class and used to demonstrate written and oral communication skills. We introduced a module on digital storytelling.

Rubric: A panel of judges evaluated the project report and technical presentation. For the report, three TAs and the instructor evaluated the outcome. Three faculty members and three TAs reviewed the presentation.

Desired result: 80% of students will meet expectations

Student performance: 100% of the students (36 out of 36) met expectations. 15 students (42% of students) exceed expectations

Observations:

Program Assessment: All Student teams delivered their projects' written reports well. Based on the judges ' comments, they also showed significant improvement in the oral presentations compared to the previous years.

Action: Separate the evaluation of written report grades and oral presentation for further granularity.

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: MENG 1000 Design Thinking

Location in Program: Early Middle End

Learning Outcome 1: 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

Instrument: Final Design Thinking Project

Methodology: Create a complete design thinking project portfolio using a certain number of Design Thinking tools that are presented gradually in class.

Rubric: See rubric below.

Desired result: 80% of students scoring Meets or Above Expectations

Students assessed: The sample consisted of 9 students, across two different academic years (2021-2022), 4 majoring in Mechanical Engineering, 2 in Graphical Design (visiting students from another institution) and 1 undecided major.

Student performance: 7 students meet or exceeded expectations, 2 students did not meet expectations.

Observations: Common errors were a failure to apply a deep enough design thinking analysis or very shallow applications of specific tools.

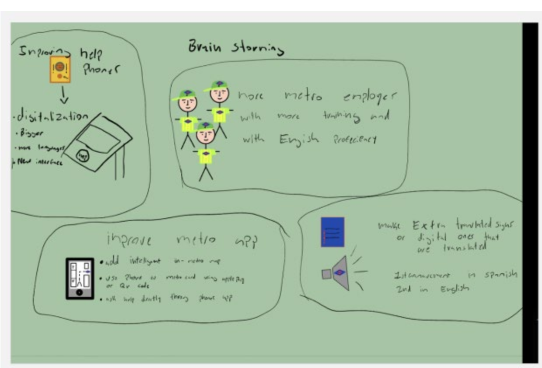
Assessment: 70% of the mechanical engineering students met or exceeded expectations.

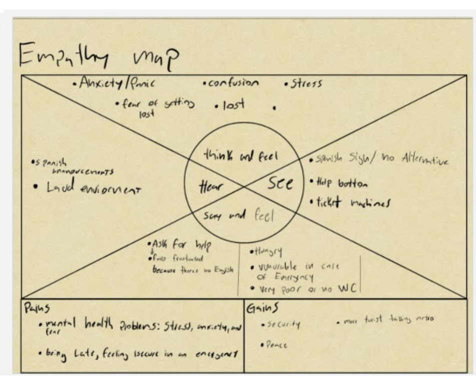
Proposed Action: This SLO shows that expectations for design outcome are met satisfactorily in MENG1000.

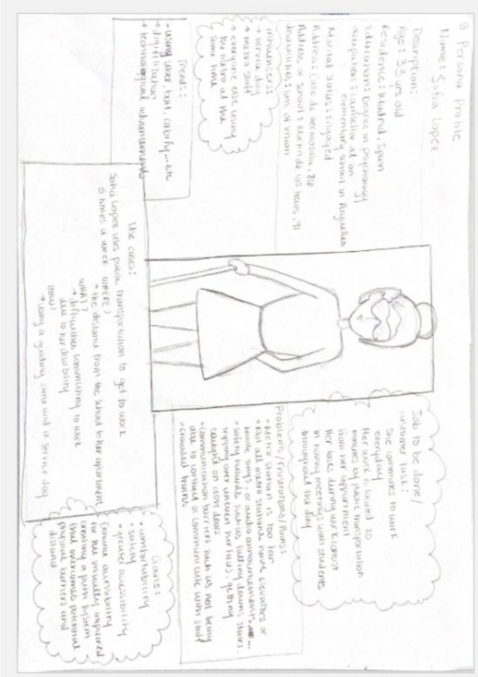
Indicator	Below Expectations	Meets Expectations	Above Expectations
Ability to create a full design thinking portfolio for a new product or service.	Student fails to produce a portfolio with the sufficient number of tools or the use of each tool is shallow and does not answer the required questions.	Student produces a report that meets more than 70% of the required tooling use.	Student produces a report fulfilling all the requirements and uses all the presented tools in depth.
Ability to create a design thinking project portfolio report.	Student fails to produce a project report detailing the design thinking process.	Student report contains t 70% of the required elements of the project.	Student report contains 100% of the elements of the project or 80% of the elements at an additional level of analysis.
Ability to orally present the project to a technical audience.	Student fails to present the design thinking process or the presented process is incomplete.	Student presentation contains 70% of the required design thinking tools.	Student presentation contains 100% of the design thinking tools effectively.

A score below 50% was treated as automatically Below Expectations, above 90% was considered automatically Above Expectations. Scores in between were assessed based on the nature of the errors and how it fit in the rubric above, with all three categories possible.

Sample instrument excerpts are shown below. All assignments starting Spring 2021 are available in Canvas.







- Age-related appreciation: People may get more appreciative of the present moment and the small pleasures in life as they get older. Spending time with loved ones, taking in the beauty of nature, or engaging in enjoyable activities may offer people joy.

Tool 2: Persona Profile

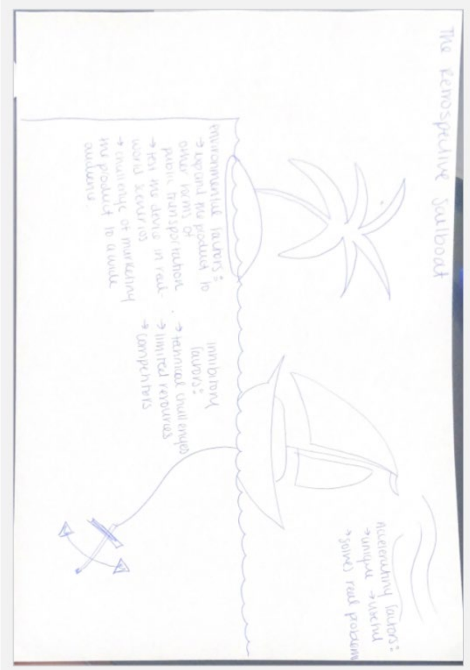
1. This is Zeina Tawfik. Zeina is from Egypt and is 72 years old. Zeina worked as a criminal lawyer for 28 years and retired in the United Arab Emirates. Zeina has been married for 30 years and is retired with her husband in Costa Rica. Zeina has 3 kids who are all adults and are working in Europe.

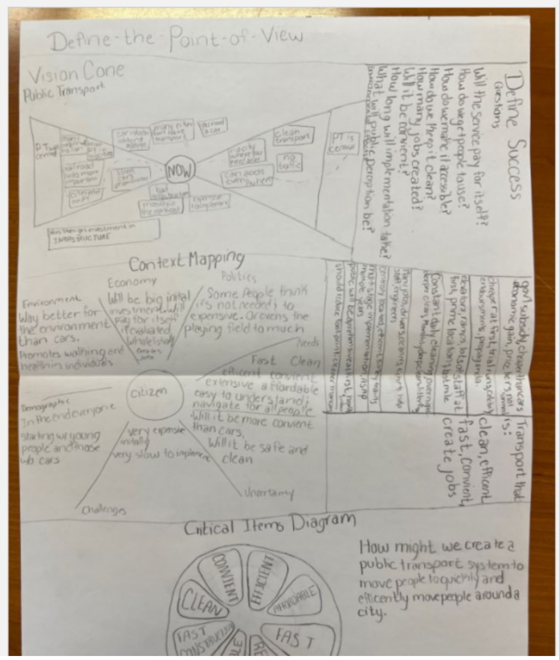
2.
- Access to healthcare: As people age, they may need additional assistance or medical attention. Making sure older people like Zeina have access to inexpensive, high-quality healthcare services can aid in their ability to maintain independence and manage their health.
- Housing and transportation: Many older people may find it difficult to find safe, inexpensive housing and transportation, especially if they have restricted mobility. It may be possible to support them in maintaining their independence and quality of life by providing resources or assistance in locating suitable housing or transportation choices.

7.
- Neighborhood leaders or advocates: Zeina participates in community organizations or advocacy groups, these individuals could be crucial in advancing her needs or interests.
- Friends and acquaintances: Zeina has made friends in Costa Rica and developed a social network there, her friends and acquaintances may also have a big impact on her life. They could offer company, assistance, or guidance.

4.
- Linguistic barriers: Depending on Zeina's level of Spanish, she could have trouble communicating in Costa Rica, which might make it difficult for her to get around and obtain resources.
- Family separation: Zeina may have less options for frequent in-person contact or assistance from family members because all of her children reside and work in Europe.

5.
- Knowledge and insight: Zeina spent many years practicing criminal law, which probably gave her a profound comprehension of people, solving disputes, and justice. She may have had special insights into the planet and its inhabitants as a result of her life experiences.
- Retirement: Zeina may be taking advantage of her newfound independence and relaxation after a long career as a criminal defense attorney. She may be able to travel, engage in hobbies, or spend time with loved ones as a result.





Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) **3 (Effective Communication)**

[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)

7 (Lifelong Learning)

Course: ESCI 3201 (Fluid Dynamics Lab) (Fall 2022)

Location in Program: Early **Middle** End

Learning Outcome 3: an ability to communicate effectively with a range of audiences

Instrument: Formal Lab Report. For Saint Louis, this is the Flat Plate Lab. The lab is conducted and data collected as a group but the lab analysis and report is done individually.

Methodology: The lab report is to be written to communicate the laboratory purpose, procedures, findings, analysis, and conclusion to professional colleagues. The lab is graded by teaching assistants and/or the instructor based on a rubric specific to this lab. Once graded, the formal labs and grading of writing-specific subsections are reviewed by the instructor and an indicator level following the rubric provided for SLO assessment is determined.

Rubric: See rubric below.

Desired result: 70% of students scoring Meets or Above Expectations

Students assessed: Three sections of this course were held in Fall 2023. Section 50 had 20 students majoring in aerospace engineering (4), civil engineering (1), engineering physics (1), and mechanical engineering (14). Section 52 had 18 students majoring in aerospace engineering (3), civil engineering (11), and mechanical engineering (3). Section 53 had 6 students, three each in aerospace and mechanical engineering. This assessment is based on the 14 mechanical engineering students in Section 50.

Student performance: Evaluation distributions for each indicator of the rubric are given in the table. The average is a total score for each student based on a simple linear average of the five indicators where Below Expectations is 1, Meets is 2, and Above is 3.

Table of Performance Indicators by Student

Ind 1	Ind 2	Ind 3	Ind 4	Ind 5	Average
2	2	2	3	3	2.4
2	3	3	2	3	2.6
2	2	3	3	2	2.4
3	2	3	3	2	2.8
2	2	2	2	3	2.2
1	1	2	2	2	1.6
2	2	2	2	2	2
3	3	2	3	3	2.8
3	3	3	2	3	2.8
2	2	2	2	3	2.2
1	2	2	2	2	1.8
2	1	3	2	2	2
2	2	2	2	2	2
2	2	2	1	2	1.8

Observations: The reports were generally followable and conveyed the information presented reasonably well. Numerous students presented incomplete or not well-constructed tables and/or plots. Most students had the appropriate sections, but a common error was either putting analysis/calculations into the Results or failing to include some text explanation and just dumping it all in the appendix. Spelling and grammar errors were uncommon (although Reynold's appeared in several papers) and were most prominent in the Summary and Introduction sections.

Assessment: The average shows three students scoring below 2, or 79% meeting/exceeding expectations. By indicator, the worst performances were Indicators 1 and 2, both at 86% meets or exceeds. Four students (with scores above 2.5/3) may be considered to have exceeded expectations.

Proposed Action: The lab course is phasing out, but this lab is likely to remain a key lab in the new Mechanics Lab. The lab does not take long to complete, so there is time for increased instruction by the TA running the lab. However, both the TA's and the students need more clarity about the expectations for the lab, and students need more and better feedback on their writing from earlier labs. It is not clear that undergraduate TA's are sufficient for this task, although more instruction for them might help as well. The reduction of the number of TA's from 4 to 2 also impacts the results from this lab.

Specific steps may be:

1) Provide a sample lab write up based on a lab being phased out of ESCI 3201 or a lab that does not require a report. This is mainly to act as a template.
2) Create more detailed solution data and expectations for each lab section for the teaching assistants, particularly regarding this outcome.
3) Have the instructor provide feedback based on this rubric in an earlier group lab to assist both the students and the TA's in understanding expectations.

Indicator	Below Expectations	Meets Expectations	Above Expectations
1) Ability to communicate in an orderly and complete manner.	Sections of the lab report are absent and/or have significant misplaced or missing material.	All required sections of the lab report are included with only occasional misplaced or absent material.	All required sections of the lab report are included with the appropriate material in each section.
2) Ability to communicate technical concepts through written descriptions, equations, data, and figures.	Report does not include needed equations, data tables, plots, and/or figures, or these items are not clear, accurate, and/or properly constructed	Report contains the equations, data tables, plots, and figures necessitated by the laboratory description These are generally accurate, complete, and properly constructed following the laboratory manual.	The equations, data tables, plots, and figures are well-constructed, accurate, and complete and are integrated into the text so as to significantly enhance the understanding of the written report by the reader.
3) Ability to use proper grammar and spelling.	Final report has numerous grammatical and spelling errors, no evidence of proofreading.	Final report has several grammatical and spelling errors, appears to have been incompletely proofread.	Final report has minimal grammatical and spelling errors, appears to have been proofread.
4) Ability to use effective writing syntax and voice.	Final report has sufficient syntax, tense, and voice issues to significantly hamper the understanding of the report by the reader.	Final report has occasional sections where the voice and tense are inconsistent or incorrect, or where the sentence/paragraph	Final report uses readily comprehensible and followable syntax and uses proper voice and tense consistently throughout

		structure is not well-organized or lacks sufficient clarity.	the report.
5) Overall communication quality.	Report fails to convey main points of the lab without significant parsing and re-reading of sections, if at all.	Report conveys information in a sufficiently logical, efficient, precise, and complete manner such that the main points of the lab are generally understood with a single read.	Report conveys information in a logical, efficient, precise, and complete manner such that the lab is fully understood with a single read.

FLAT PLATE BOUNDARY LAYERS

OBJECTIVE

In this lab you will learn methods to:

- Measure flat plate boundary layer velocity profiles under laminar and turbulent conditions
- Compare velocity profile measurements to accepted theoretical values

INTRODUCTION

Flow in contact with a wall is assumed to match the velocity of the wall (no-slip condition). Thus moving away from the wall, the fluid must transition from the velocity of the wall to the velocity of the freestream, which is the primary flow velocity. This creates a region called the boundary layer in which the flow speed is between the wall and the freestream. The thickness of the boundary layer is often labeled as δ. In the case of flow over a stationary flat plate, this thickness increases as the flow moves down the plate as shown in Fig. 1.

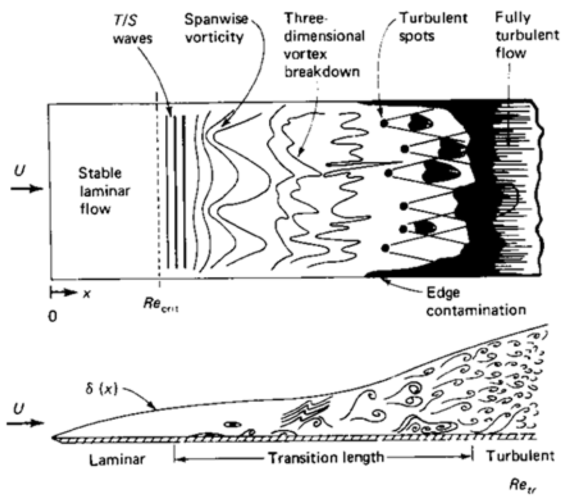


Figure 1: Natural transition of a laminar-turbulent boundary layer on a smooth flat plate

Initially, this example assumes the flow is laminar on the first part of the plate. Ideally, laminar flow has streamlines that do not interact and the flow moves in roughly parallel planes. However, as the flow moves further along the plate, small vortices begin to form near the surface. As these vortices decay, the flow becomes increasingly turbulent. Turbulent flow exhibits strong mixing of mass, momentum, and energy through vortices and eddies. The process of shifting from laminar flow to turbulent flow is called transition, and it is a complex process which can take multiple forms, one of which is shown looking down on the plate in Fig. 1.

The most common parameter used in determining if flow is laminar or turbulent is the Reynolds number (Re). Reynolds number is a dimensionless quantity representing the ratio of momentum or inertial forces to viscous forces in a boundary layer. It is a function of fluid density, freestream velocity, plate length from the leading edge to the point of interest, and fluid dynamic viscosity. A common approximation for a smooth flat plate is that transition from laminar to turbulent flow takes place when the Reynolds number as a function of the distance along the plate reaches a critical value, typically $Re_x = \rho Ux/\mu \sim 5\times10^5$., where x is the distance along the plate from the leading edge, U is the freestream velocity, and ρ and μ are the fluid density and viscosity. If the plate is rough, the turbulent boundary layer will begin at lower Reynolds numbers (i.e. closer to the leading edge assuming all else is equal).

A way to investigate boundary layers is to match experimental data to approximations of boundary layer profiles and then determine the flow characteristics based on the best-fitting approximations. The profile is typically written as a ratio of the local velocity u to the freestream velocity U equal to a function of the ratio of the normal distance to the surface of the plate y to the boundary layer thickness δ. Two approximations have been shown to work well:

$$\frac{u}{U} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$ Nikuradse cubic approximation for **Laminar B.L.** (1)

$$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{\frac{1}{7}}$$ Power law profile for **Turbulent B.L.** (2)

EXPERIMENT

1. Record the ambient temperature and pressure in the room.
2. Determine the wind speed the tunnel must run below to ensure laminar flow over the smooth plate. This means the Reynolds number must be kept below the transitional value for air flow over a flat plate.
3. Knowing the wind speed and the Reynolds number, calculate the respective maximum dynamic pressure. Dynamic pressures measured during this lab should not exceed this value. If they do, you need to recheck your calculations or adjust the airspeed of the apparatus. Be aware that the probe is a Pitot-static tube where the tip of the tube reads total pressure $P_T = (½\,\rho V^2 + P)$. The manometer in Lab View will present dynamic pressure based on comparing the static and total pressures.
4. Put the plate into the test section with the smooth side facing the probe and micrometer. Adjust the micrometer so that the probe *just* touches the plate surface. To ensure that it is placed correctly, you should be able to slide a piece of paper between the probe and plate while encountering only a slight resistance. Note the distance from the leading edge of the plate to the location of the pitot-static probe as this is the distance x in the Reynolds number calculation.

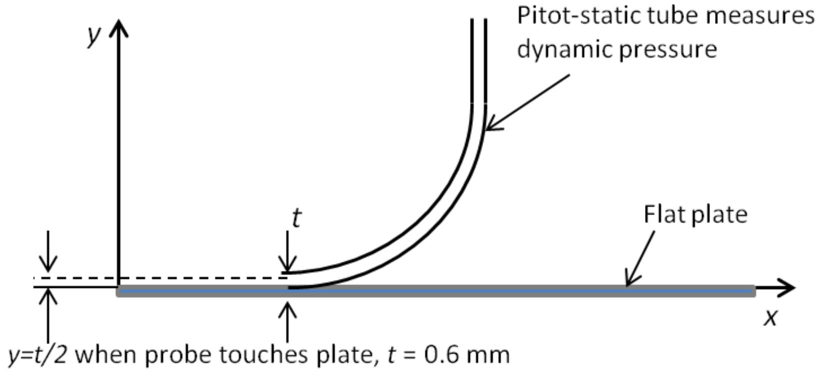


Figure 2: Pitot-static tube conventions

5. Take at least 5 pressure readings in Lab View for every 0.2 mm movement of the probe until the probe is out of the boundary layer. **(How does one know when the probe is out of the boundary layer?)** Once you have all your data, remove the highest and lowest values from each point and average the values that are left. That will be the value for that point. **(How many points might be appropriate to take given small sample errors?)**
6. Perform Step 4 and Step 5 with the **rough** side of the plate facing the probe to attempt to induce larger Reynolds numbers. You can also slide the plate further toward the wind inlet to assist in this endeavor since the Reynolds number also depends on the plate length covered by the flow before the pitot-static tube.

DATA ANALYSIS

1. Plot two figures.
   a. Experimental smooth side distribution AND both the laminar and turbulent velocity distribution approximations from Eq. (1) and (2).
   b. Experimental rough side distribution and its approximations from Eq. (1) and (2).

   Remember that the x-axis and y-axis are normalized so their maximum values should be about one.

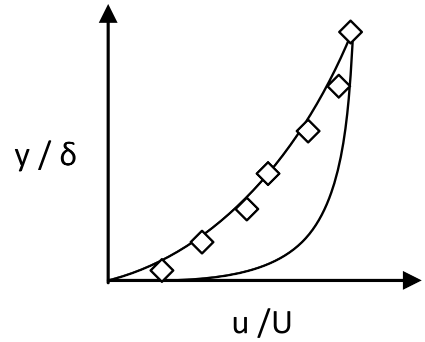


Figure 3: Example velocity profile graph

2. Compute the difference at each y/δ point between the experimental normalized velocity and both the laminar and turbulent approximations in equations 3 and 4. Place these differences in a table in your report. These differences can be multiplied by 100 to obtain the local percent error (you do not need to divide the difference in this case since all of the values are normalized already). These local percent errors should be aggregated together and averaged to obtain a mean percent error for that comparison. This should be done for four cases: smooth (experiment) vs. laminar (theory), smooth (experiment) vs. turbulent (theory), rough (experiment) vs. laminar (theory), rough (experiment) vs. turbulent (theory). Discuss these percent errors as indications of whether or not laminar or turbulent flow was observed in each side of the plate (it might not be smooth = laminar, rough = turbulent; if neither, what would it be? Refer to Fig. 1 to help answer this). Also discuss possible sources of error in these results and their possible effects.
3. Compute the small sample (t-distribution) error range on three selected points (one near the bottom, one in middle, one near the top of the boundary layer) for the rough and smooth plate data sets assuming 90%/95% confidence. What, if any, are the implications of this measurement error on the discussion of Step 2?
4. Obtain the percent error between the experimental calculation of δ/x (non-dimensional boundary layer thickness where x is the length term used in Reynolds number equation) and the empirical equations below. In total there should be four cases with percent error (same as step 2). Discuss what these results imply about the boundary layer structure (for example laminar v. turbulent) and uncertainties associated with this analysis approach.

	δ / x
Laminar Cubic Approximation	$4.6/(Re_x)^{1/2}$
Turbulent Power Law Approximation	$0.37/(Re_x)^{1/5}$

APPENDIX

Useful Equations

Density: $\rho = \frac{P_{room}}{RT_{room}}$ (R = 287.2 $\frac{Nm}{kgK}$ and T in K)

Coefficient of absolute viscosity: $\mu = 1.458 \times 10^{-6} \frac{T^{1.5}}{T + 110.4} \quad \frac{kg}{s \cdot m}$

Reynolds's Number: $Re_x = \frac{V \cdot x}{\nu}$ Kinematic viscosity: $\nu = \frac{\mu}{\rho}$

Distance from plate: y = micrometer reading - micrometer reading at plate + t/2

Boundary Layer thickness: δ Determine by observation of data (u/U = 1)

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) **3 (Effective Communication)**

[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)

7 (Lifelong Learning)

Course: <u>MENG 4014 (Senior Design 2), spring 2023</u>

Location in Program: Early Middle End

Learning Outcome 3: An ability to communicate effectively with a range of audiences.

Method: Powerpoint presentations, written final reports, class participation

Rubric: A score of 3.0 and above on a scale of 5.0 (5-Outstanding, 4-Excellent, 3-Good, 2-Satisfactory, 1-Poor)
1. Below Expectations: Fails to address considerations named in the learning outcome
3. Meets Expectations: Student addresses considerations named in the learning outcome
5. Exceeds expectations: Student works with team to modify and modify own initial thoughts and to address considerations named in the learning outcome.

Desired result: 70% of students will meet expectations by earning a grade of 3 or higher

Student performance: 34 of 37 students (91.9%) met expectations (average score 3.89)

Observations: The students worked on six teams of 5-7 students to design a robot to paint field lines in sports fields, a system to desalinate water using solar energy, a beach-cleaning device, a cooling system for campers, a salt spreader to melt ice, and a self-propelled chair for handicapped people. The criterion was evaluated by considering the average of 3 elements: individual class participation through the semester in providing useful comments to improve the designs of other teams, evaluated by the instructor; the final report; and the final powerpoint presentation. The final report was prepared to formal team communication to strict specifications described in the syllabus for engineering company management; and the powerpoint presentations (project team presentations) were evaluated by fellow students, faculty, and industry representatives.

All students met the requirement for powerpoint presentation (100%, average 3.81)
All students met the written report requirement (100%, average score 4.00)
34 of 37 students met the class participation communication requirement (91.9%, average score 3.68)
Overall 34 of 37 students were awarded average of 3.0 or higher (91.9%, average score 3.89)

Program Assessment:
91.9% of the students demonstrated ability to communicate with a range of audiences (average score 3.89).

Action: Continue emphasizing the importance of various forms of communication in engineering settings.

Criterion 3: Assessment by the instructor:
It seems the majority of the weaker members in the class got to work together in one team (the Jaguars). This affected project outcomes and team member contributions to the project. Two of the team members pulled the rest of the team throughout the two-semester sequence.
All students who did not meet the criterion were in that team.
All other teams performed very well.

Respectfully submitted
Theodosios Alexander, Sc.D.
Professor of Aerospace and Mechanical Engineering
Parks College, SLU

AEME ABET Assessment Review Form

This form is a summary of the collective departmental review of learning outcome assessment, to be used to record review group thoughts about assessment materials collected.

Program (AE or ME): ME Date materials reviewed: 11/11/2023

Criterion reviewed (circle one): 1 2 3 4 **5** 6 7

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

Semester(s) reviewed: Fall 2022, Spring 2023 (primarily)

Reviewers: Alexander, Babaiasl, Condoor, Gururajan, Jayaram, LeBeau, Ma, Marmolejo, Swartwout

Courses and instruments:

Course	Semester	Description (ind/Grp)	Level	Team Mgmt	Collab
ESCI/SE 1700	AE (F); ME (F)	Instructor assessment, possibly some type of student survey	Early Formative	Y	Y
ESCI/MENG 3101	AE (S); ME (F)	Student survey	Middle Formative	Y	Y
MENG 3111	AE (F); ME (S)	Student survey	Middle Formative	Y	Y
MENG 4004	ME (F)	Final Presentation (group)	Late Formative	Y	Y

Strengths and weaknesses:

Where do we develop/teach teamwork skills (as opposed to practice)? We have many courses with team activities across the curriculum, but do not generally present teamwork skills, more of a learn as you go approach.

Project management starts in MENG 1000 but may need reinforcement before senior design. Need to better consider individual teamwork roles in assessment beyond student self-surveys

In final evaluation, most teams appear to at least meet expectations based on available data and other observations.

Recommendations and proposed actions:

Work with ROTC to create first-year team building exercise

Adapt MENG 3101 survey to MENG 3111 (include the major question), Adapt MENG 4004 approach to MENG 4304/4024.

Consider using a team evaluation software package across multiple classes (see what happens in SE 1700)

Other comments:

This was the first review of this outcome under the newly revised assessment plan of August 2022.

Learning Outcome: **1 (Solve Problems using SEM)** 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: ESCI 3101 (Mechanics of Solids Lab) (Fall 2022)

Location in Program: Early Middle End

Method: Survey

Rubric: 75% of students should have average or above average team performance score

Desired result: 100% of students will meet expectations of 75% or more (data not separated between AE and ME students in this case)

Student performance: 100% of students met expectations

Observations: None

Program Assessment: Acceptable performance

Action: No action needed

	Team members availability	Ability to listen to other members	Minutes of the meeting	Individual Contribution	Knowledge of other's contribution	Passive information gathering
	Rate the availability of members for discussion through a scheduled meeting, on-line chat, e-mail, phone etc	Listen to ideas and perspectives with an open mind	Documenting the discussion on each agenda item, dissemination to all members in a timely manner	Extent to which the members fulfilled their assigned task, additional voluntary contributions	Extent to which each member is aware of what other member contributed to the project	Ability to get information through books, magazines, journals, web search etc
Average	4.2	4.8	4.3	4.5	4.3	4.2
Median	5	5	4	5	5	4

Active information gathering	Appreciation for other's work	Completion of task on time in a collaborative inclusive manner	Overall effectiveness of team	Leadership qualities emerge in team members
Ability to get information through direct communication with faculty, industry, or other experts in the field	Ability to appreciate the work of other members without bias and prejudice	Ability of team members to make a schedule and follow it until the completion of task	Ability of members to work towards the common goal of the project by helping each other.	as the project moves through completion.
4.6	4.7	4.3	5	4.5
5	5	4	5	5

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) **5 (Functional Teamwork)** 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: MENG 4004 (Senior Design 1), fall 2022

Location in Program: Early Middle End

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.

Method: Homeworks 1 2 and 3. Supportive documentation in Final Reports.

Rubric: A score of 3.0 and above on a scale of 5.0 (5-Outstanding, 4-Excellent, 3-Good, 2-Satisfactory, 1-Poor)
1. Below Expectations: Fails to address considerations named in the learning outcome
3. Meets Expectations: Student addresses considerations named in the learning outcome
5. Exceeds expectations: Student works with team to modify own initial thoughts and approaches to address self improvement and develop leadership skills, as well as create a collaborative and inclusive environment, establishing team goals, plan tasks, and meet objectives.

Desired result: 70% of students will meet expectations (score 3.0 or higher)

Student performance: 91.9% of students met expectations (average score 3.92)

Observations: The students worked on six teams of 5-7 students to design a robot to paint field lines in sports fields, a system to desalinate water using solar energy, a beach-cleaning device, a cooling system for campers, a salt spreader to melt ice, and a self-propelled chair for handicapped people. In Hwk 1 the students stated how they viewed their own work and contributions to the team. In Hwk 2 the students in each team graded other team members on leadership, participation, contributions, communications, as well as critiqued where each team member could improve. In Hwk 3 the teams worked internally to identify areas in which each team member would develop leadership, communication, participation, contribution etc., and worked together to achieve improvement in each individual team member. Two students were consistently absent or not participating in their teams habitually, and the teams carried them for a while, but then informed these students to shape up. This improved participation by these 2 students marginally. One student was frequently absent on athletic trips, and this limited his ability to participate meaningfully throughout the sequence of 4004 and 4014. Thus overall 3 students of 37 did not meet outcomes, 2 due to bad practices, and 1 due to SLU approved outside commitments.

Program Assessment:
91.9% of the students were able to develop individual leadership skills, step-management skills, and worked in teams to produce solutions that met project (and course) objectives.

Action: Continue emphasizing the importance of teamwork, collaboration, accountability, engineering skills, leadership skills, and step management skills in meeting engineering project objectives.

Criterion 5: Assessment by the instructor:
91.9% of students met expectations (average score 3.92). Initially each team fell back to obeying the orders of one dominant team member, and many team members were unhappy. With a series of exercises in homework 1 (individual responses) and 2 (team responses) I challenged the students to identify what was working well and what was not and discuss amongst them how to bring leadership skills and contributions from each individual team member to the project. After completion of homework 2 all teams performed extremely well in MENG 4004, and as an outcome every team and 34 of 37 students met criterion 5, as is evident in the answers to homework 2, 3, and final reports (and presentations, not used for assessment here).

Respectfully submitted

Theodosios Alexander. Sc.D.
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Parks College, SLU

5	excellent	Critical thoughts, adjusted path after reflection
3	average, acceptable	Considered and implemented basic requirements
1	poor	Superficial treatment

Scores:

Criterion 5
Team
Hwk 123, PPt, Report
5
1
5
4
4
5
4
3
1
3
5
5
5
5
5
4
4
5
5
5

3
4
3
3
1
3
4
3
5
2
5
5
3
4
4
5
5

Introduction to Homework 1:

This is individual work, **without prior discussion or collaboration with your teammates or classmates**. Your submissions will only be reviewed by the instructor, and will remain confidential from all other teammates and classmates. Please answer each of the questions with 3-5 sentences or specific items, or more if needed. **This is a self-reflecting study, not a quiz, and the objective is to assess how we progress in our thought patterns, learning, and teamwork through the course.**

Note, homework 2 will have similar questions, later in the course, where there will be one answer per team.

ABET criterion 5 (fall 2022, MENG 4004): 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

Homework 1 individual submission (confidential input to the instructor): ABET Criterion 5) What and how have you contributed to the team's effort to date (e.g. leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives)?

a. Itemize in what you have personally contributed towards project planning and documenting including schedules, agenda, weekly team reports or minutes, and dissemination in a timely manner.
b. Itemize what you have personally contributed towards completion of tasks on time in a collaborative inclusive manner, to meet schedules, and follow tasks to completion?
c. temize what you have personally contributed towards passive information gathering from the public domain (books, magazines, journals, web searches etc.)
d. Itemize what you have personally contributed towards active information gathering through interaction with faculty, industry, or other experts.

Grading scale for answers to the questions below										
Very Low		Low			Medium			High		Very High
0	1	2	3	4	5	6	7	8	9	10

a. How would you rate yourself on your ability to listen to other team member’s ideas and perspectives with an open mind?
b. How would you rate yourself on awareness and appreciation for other’s work without bias and prejudice?
c. How would you rate yourself on trusting the validity and accuracy of the contributions of other team members?
d. How would you rate yourself on your availability for discussion through scheduled meetings, zoom, on-line chats, e-mail, phone etc.?
e. How would you rate yourself on individual contributions to which you fulfilled your assigned tasks, and on additional voluntary contributions?
f. How would you rate the contributions of team interactions to date towards your personal growth and improvement?
g. How would you rate the contributions of team interactions to date towards improvement of your personal leadership qualities?
h. How would you rate your team on ability to work towards the common goal of the project by helping each other?

Which members of your team have contributed more, which have contributed average, and which members of your team have contributed less to date? What are the reasons for discrepancies in contributions from various members of the team? Do you intend to make any changes from now on? What action will you take to steer the team towards these changes?

Homework 2 (Individual, about other team members)

a) What has the team member personally contributed towards planning and documenting, including schedules, agenda, weekly team reports and minutes, and dissemination of project outputs in a timely manner?
b) What has the team member personally contributed towards completion of tasks on time in a collaborative inclusive manner, to meet schedules, and follow tasks to completion?
c) What has the team member personally contributed towards passive information gathering from the public domain (books, magazines, journals, web searches etc.)
d) What has the team member personally contributed towards active information gathering through interaction with faculty, industry, or other experts?
e) How would you rate this team member on ability to listen to other team member’s ideas and perspectives with an open mind? (Note, half of the team has to be below team medium)
f) How would you rate this team member on awareness and appreciation for other’s work without bias and prejudice? (Note, half of the team has to be below team medium)
g) How would you rate this team member on trusting the validity and accuracy of the contributions of other team members? (Note, half of the team has to be below team medium
h) How would you rate this team member on availability for discussion through scheduled meetings, zoom, on-line chats, e-mail, phone etc.? (Note, half of the team has to be below team medium)
i) How would you rate this team member on individual contributions to which the team member fulfilled assigned tasks, and on additional voluntary contributions? (Note, half of the team has to be below team medium)
j) How would you rate this team member's personal growth and improvement through team interactions to date? (Note, half of the team has to be below team medium)
k) How would you rate this team member's improvement in leadership qualities through team interactions to date? (Note, half of the team has to be below team medium)
l) How would you rate this team member's ability to work towards the common goal of the project by completing own tasks well and on time, and by helping other team members? (Note, half of the team has to be below team medium)
m) What has this team member done well for the team and project?
n) What could this team member do better in the future for the team and project?
o) In what aspect of personal leadership, work attributes, communications etc. could this member strive to improve for the future benefit of the team and project, and possibly for their own professional growth?

Homework 3, due 11:59 pm on Tue Nov 8 2022, Canvas Submission per team

This is in collaboration with your teammates, but not your classmates outside the team. One submission per team. Please answer each of 3 questions with specific and concrete items, succinctly, but also in appropriate detail. For instance, in some parts of question 2 a specific answer for each team member is required, and there are many parts in question 2.
This is a self-reflecting study, not a quiz or exam, and the objective is to assess how we progress our thought patterns, individual growth, learning, and teamwork through the course.
ABET Criterion 5)

a. What processes is your team using to create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives in consultation with the whole team? Do these need any modifications to be more inclusive for any of your team members?
b. What processes are you using to identify individual team-member goals and strengths, and align these with team goals in the project? List the strengths of each team member.
c. Discuss among you candidly the weaknesses of each team member. The team should provide constructive suggestions for improvement to each team member, and document this in a confidential team document. Confirm that this is done for each team member, but do not write anything specific in your answer (I do not need to read it).
d. What processes will you use to allow growth of leadership skills in each individual team member? A separate answer for each team member is required.
e. Keep in mind everyone performs better if they have pride, ownership, and take lead in some aspect of their work. Itemize leadership areas targeted for each individual team member.
f. Itemize growth areas for each individual team member.
g. Itemize target areas to achieve growth for each individual team member.
h. How will you measure successful outcomes for each team member in items e?
i. How will you measure successful outcomes for each team member in items f?
j. What additional processes do you think you may introduce from now to the end of the fall semester to address the above matters?

AEME ABET Assessment Review Form

This form is a summary of the collective departmental review of learning outcome assessment, to be used to record review group thoughts about assessment materials collected.

Program (AE or ME): AE Date materials reviewed: 11/11/2023

Criterion reviewed (circle one): 1 2 3 4 5 6 **7**

an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Semester(s) reviewed: Fall 2022, Spring 2023 (primarily)

Reviewers: Alexander, Babaiasl, Condoor, Gururajan, Jayaram, LeBeau, Ma, Marmolejo, Swartwout

Courses and instruments:

Course	Semester	Description (ind/Grp)	Level		
ESCI/SE 1700	AE (F); ME (F)	Bibliography Exercise	Early Formative		
MENG 2000	ME (S)		Middle Formative		
MENG 2450	ME (S)		Middle Formative		
MENG 4014	ME (S)		Late Summative		

Strengths and weaknesses:
Library personnel participation is effective for students
Students generally demonstrate appropriate library and bibliography skills

Recommendations and proposed actions:
Examine incorporating Cura Personalis 3 artifacts
Need improved/additional artifacts for senior design projects

Other comments:
This was the first review of this outcome under the newly revised assessment plan of August 2022.

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: ESCI 1700 (Engineering Fundamentals) (Fall 2022)

Location in Program: Early Middle End

Method: *As part of their design project, students were tasked with creating bibliographies. The bibliographies were separately submitted by each student. In the assignment, students were required to identify a research question, find 3 sources that addressed the question and justify their inclusion. The students also had to find and implement a citation style appropriate to their work (e.g., an AIAA or ASME style). Successful completion of this assignment required them to define an open-ended question and use the SLU library system for collecting the information and finding the citation style, all of which are evidence of early achievement in lifelong learning.*

Rubric: *A standardized rubric was used (included). The instructor for the student's section graded the assignment using the rubric. For each of three research questions, the student was graded on the quality of the research question relative to the design project (6pts), finding 3 relevant sources using the library (12 pts) and justifying the relevance of each source (9 pts) – 81 points total. An additional 9 points were for finding and implementing a technical citation style.*

Desired result: 70% of students will meet expectations (defined as scoring 80% or higher in the rubric)

Student performance: 24 of 30 students submitted the assignment
22 of 24 assignments were graded using the rubric
20 of 22 graded assignments (91%) met expectations

Observations: *Among those graded, the average score was 89% and the median was 95%. The two who submitted the assignment but did not meet expectations were well below the threshold (7% and 57%, respectively). Generally speaking, those who did not meet expectations did not follow the assignment requirements, using general web searches instead of archival journal/article searches.*

It is observed that entry-level engineering students have been well-trained in gathering bibliographies and citing sources. They had little problems completing this assignment, and scored quite well compared to other parts of the design project.

The course had 150 students across 7 sections and 5 instructors, with the 30 MENG students scattered among all the sections. One of the instructors chose not to use the rubric in grading the assignment.

Program Assessment:
Assuming that the results are valid, then perhaps we can expect more of our entry-level students.

Action: *[Recommended responses]*

Points Possible	90	
ME1		
ME2		
ME3	86	Meets Expectations
ME4	90	Meets Expectations
ME5	86.5	Meets Expectations
ME6	88	Meets Expectations
ME7	86.5	Meets Expectations
ME8	85	Meets Expectations
ME9		
ME10	73	Meets Expectations
ME11	81	Meets Expectations
ME12	86	Meets Expectations
ME13	85	Meets Expectations
ME14	6	Does Not Meet Expectations
ME15	85	Meets Expectations
ME16	86.5	Meets Expectations
ME17	90	Meets Expectations
ME18	51	Does Not Meet Expectations
ME19	90	Meets Expectations
ME20		
ME21		
ME22		
ME23		
ME24	87	Meets Expectations
ME25		
ME26	87	Meets Expectations
ME27	80	Meets Expectations
ME28	90	Meets Expectations
ME29	81	Meets Expectations
ME30	85	Meets Expectations

Criteria	Ratings					Pts
First Research Question The research question is a) relevant to your part of the project, b) involves a question to be answered or something to be learned, and c) is narrow enough that it can be resolved with a search.	**6 pts** **Full Marks**	**5 pts** **Some answers are incomplete or missing**	**4 pts** **Mostly there**	**2 pts** **Lots of missing items**	**0 pts** **Didn't do this**	6 pts
Second Research Question The research question is a) relevant to your part of the project, b) involves a question to be answered or something to be learned, and c) is narrow enough that it can be resolved with a search.	**6 pts** **Full Marks**	**5 pts** **Some answers are incomplete or missing**	**4 pts** **Mostly there**	**2 pts** **Lots of missing items**	**0 pts** **Didn't do this**	6 pts
Third Research Question The research question is a) relevant to your part of the project, b) involves a question to be answered or something to be learned, and c) is narrow enough that it can be resolved with a search.	**6 pts** **Full Marks**	**5 pts** **Some answers are incomplete or missing**	**4 pts** **Mostly there**	**2 pts** **Lots of missing items**	**0 pts** **Didn't do this**	6 pts
Reference 1-1 [Note: the first number is the question, the second is the reference] The reference is from a Libraries search, and addresses the research question (Repeat for references 1-2, 1-3, 2-1, 2-2, 2-3, 3-1, 3-2, 3-3)	**4 pts** **Full Marks**	**3 pts** **Library search but relevance is iffy**	**2 pts** **Not from a library search**	**1 pts** **Not from the library, doesn't seem to address the question**	**0 pts** **Didn't do this**	4 pts

Explanation for Reference 1-1 [Note: the first number is the question, the second is the reference] Explains why this reference was selected and what was learned (Repeat for references 1-2, 1-3, 2-1, 2-2, 2-3, 3-1, 3-2, 3-3)	**3 pts** **Full Marks**	**2.5 pts** **Decent effort, but incomplete answers**	**1.5 pts** **Only did 1 of the 2 (why selected or what was learned)**	**0 pts** **Didn't do this**	3 pts

Found a technical citation style	**3 pts** **Full Marks**	**2.5 pts** **Found a style, but it's not a technical one**		**0 pts** **Did not cite a style**	3 pts
Implemented the Style consistently	**6 pts** **Full Marks**	**5 pts** **Mostly there**	**3 pts** **A few egregious mistakes**	**0 pts** **Wildly inconsistent or no style evident**	6 pts
					Total Points: 90

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: MENG 2000 Foundation to Engineering Design (F2022)

Location in Program: Early **Middle** End

Learning Outcome 7: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Instrument: Design Project

Methodology: *Students were given design spaces to innovate, design and prototype a product. Students are expected to perform user research, learn about the needs, identify the main opportunities, and implement the prototype. The design requires the students to pull and synthesize information from a variety of sources. Also, they need to learn new hardware components/software commands for Arduino.*

Students are assessed on their ability to find and synthesize information in creating an innovative product.

Desired result: 70% of students at least 80% on the rubric

Student performance: 15 of 34 students exceeded expectations (44%)
32 of 34 students met expectations (94%)
2 of 34 students didn't meet expectations (6%)

Students who didn't meet observations due to the lack of effort put into the project.

94% of the mechanical engineering students met or exceeded expectations.

No action is needed.

COVER PAGE

OVERVIEW OF THE PROBLEM/NEED (15 points) (3 Paragraphs + Use the market research that you learned in MENG-1000 – Design Thinking course)

TARGET CUSTOMER (15 points) (2 paragraph – specific description; Summary of customer observations & interview 2-3 paragraphs – Actual transcripts + pictures in the appendix)

PRODUCT POSITIONING (30 points)
i. AD (EXAMPLE – USE CAD MODEL -> PHOTOSHOP -> ADD BENEFITS/FEATURES)

Wolezek Plant Light for Indoor Growing- Suitable for All Indoor Plants

ii. SHOW COMPETITION AND HOW YOUR PRODUCT WILL DIFFER

	4-Head Grow Light with Stand	4-Head Floor Plant Light	3-Head Clip Grow Light	T8 Indoor Grow Light Strips	T8 Indoor Plant Lights	5-Head Grow Light with Stand
LED Quantity	80 LEDs	80 LEDs	315 LEDs	384 LEDs	384 LEDs	105 LEDs
Placement Type	15-48 Inch Adjustable Stand	15-48 Inch Adjustable Stand	Clamp Grow Light	4 Pack Light Strips	4 Pack Light Strips	15-48 Inch Adjustable Stand
Timer Function	4/8/12H	4/8/12H	3/6/12H	No timer	No timer	4/8/12H
Remote Control	✓	✓	X	X	X	✓
Dimmable	✓	✓	✓	X	X	✓
LED Bulb	Red/Blue/Warm White	Red/White/Warm White	Warm White	Red/White/Warm White	Red/Blue/Warm White	Red/White/Warm White

PROTOTYPE (30 points)

1. What are you demonstrating with the prototype?
2. Specifications
3. Hardware Schematic
4. Flowchart of the logic
5. Code
6. Testing protocol

OVERALL REPORT QUALITY (10 POINTS)

Learning Outcome: 1 (Solve Problems using SEM) 2 (Design in Global Context) 3 (Effective Communication)
[select 1] 4 (Ethics in Global Context) 5 (Functional Teamwork) 6 (Experiment and Draw Conclusions)
7 (Lifelong Learning)

Course: MENG 2000 Foundation to Engineering Design (F2022)

Location in Program: Early **Middle** End

Learning Outcome 7: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Instrument: Bridge-building competition (instructions included).

Methodology: Students are instructed to build a bridge using popsicle sticks and glue. Students are expected to perform research on bridge design and identify the main opportunities for optimization their design. Projects are graded on the ingenuity of the design, the 'budget' for building it, and the bridge's load-carrying ability.

Rubric: See instructions attached.

Desired result: 70% of students scoring Meets or Above Expectations

Students assessed: The class consisted of 5 mechanical engineering students.

Student performance: 2 students had 'Above Expectations' and 3 students had 'Met Expectations'.

Observations: Students properly identified the problem or need for which they were designing a solution. The bridge designs were functional and demonstrated good understanding of the design principles.

Assessment: 100% of the mechanical engineering students met or exceeded expectations.

Proposed Action: No action is needed.

MENG 2000

Foundations to Engineering Design

Project 1

Bridge Building Contest

Synopsis

During the last electoral cycle for a new mayor in the great town of Elmirsville, Dr. Charles El Mir emerged as the clear winner. Unfortunately, he is long overdue on his electoral promise to "Build that Bridge", and his poll numbers have been quickly plummeting. With his eyes set out for re-election, he sent a 'request for proposal' (RFP) to local engineering firms that are specialized in building bridges.

The mayor outlined his request as follows:

- The bridge needs to be aesthetically appealing.
- Cars need to be able to cross the bridge.
- The bridge needs to support as much weight as possible.
- The bridge needs to connect two pieces of land separated by a flowing river.
- The bridge needs to be economical. The mayor has already spent most of the town's budget.

To select the winning bid, the mayor requires each participating company to provide a prototype of the bridge they intend to build. The prototype will then be tested, and the winning company will be granted the contract.

Guidelines for the bridge prototype

The bridge must be constructed uniquely from popsicle sticks held together by standard white glue. Such a stick is provided herein for inspection. Construction materials can only be purchased from ElmirDepot *(a decision viewed by many as controversial, since the mayor himself owns the company)*. Bridges containing any other material, whatsoever, will be automatically disqualified.

The bridge must span a clear distance of 60 cm and can, at most, have a length of 70 cm. The bridge must have a continuous flat deck that is at least 10 cm wide, and at most 20 cm wide. This roadway should allow a small 'matchbox'-type car to roll through without stopping or falling off the bridge.

The maximum height above the deck should be less than 20 cm, and the bridge should protrude no more than 5 cm below the bottom of the deck.

The prototype will be simply-supported (resting) between two flat surfaces separated by 60 cm. The bridge cannot have any other types of supports.

The bridge should not weigh more than 550g and, ideally, should not be made with more than 300 popsicle sticks.

Materials

The market price for the materials required for building the bridge are:

Material	Qty	Unit	Price (USD)	
Popsicle Sticks	1	each	Pre-bid	1000
			Post-bid	2000
Glue	50	g	Pre-bid	5000
			Post-bid	6000

Table 1.1: Pricing of the materials used in the bridge construction

There will be an initial supply of materials, during the pre-bid stage, at a reduced cost. Any additional materials requested after the initial stage will include a surplus.

Scoring

The prototypes will be ranked according to aesthetical appearance, best estimated load capacity, actual load capacity, efficiency rating, estimated cost (first bidding round) and final cost.

The aesthetics will be scored by a panel of judges. The bridges will then be ranked based on the scores' aggregates.

Prior to testing, each company must report the estimated (or theoretical) load capacity that their bridge is designed for. The 'best estimated load capacity' will be measured in terms of ratio of the actual load capacity to the estimated load capacity.

The Efficiency Rating (ER) is defined as the ratio of the maximum load supported by the bridge divided by the bridge's weight. High ER's are linked to low overall bridge weight.

The relative weights for the bridge design score will be as shown in Table 1.2.

Scoring Category	Score
Aesthetics	5
Conformity with Requirements	10
Estimated Load Capacity	15
Presentation	15
Maximum Load Capacity	25
Efficiency Rating	30
Lowest Budget	15 (Bonus)
Total	100 + 15 Bonus

Table 1.2: Score breakdown

Bidding Procedure

The competing companies have until February 21st, 2022 to submit their formal Expression of Interest (EOI). The letter should state the company's name and identify the lead engineers that will be working on this project.

Should companies require additional information, they may supplement the EOI with a Request for Information (RFI) that includes any requests and clarifications.

The first round of bidding will take place on February 28th, 2022. Companies must submit their first proposal, which must include a schematic of the bridge to be constructed, the total budget requested, and an itemized breakdown of the materials.

The company with the lowest budget will be awarded with additional bonus points. The remaining companies with higher bids will be allowed to revise their budget for re-consideration on the same day. The remaining companies will then be ranked based on their final proposed budget. It is therefore wise to have multiple design options prepared beforehand.

The companies will be provided with the construction materials at the end of the bidding process.

Additional Material Requests

Should a company require additional materials after the initial bid, it must submit a request form to ElmirDepot detailing the amount of each item needed. The materials will be delivered on the following working day.

Testing Procedure

All prototypes will be tested on March 14th, 2022.

The bridges will be weighed and then loaded until failure. The maximum carried load before failure will be recorded. The load will be applied using a ~1.5 diameter steel rod placed at the center of the bridge. All bridges must be designed to accommodate this rod. The bridge is considered capable of safely carrying a given load if it can sustain it for at least 10 seconds without failing.

The mayor retains the right to alter the testing date, depending on his occupation with town-related business.

Final Report

At the end of the prototype testing stage, all companies must present a final report that includes:

1. Executive summary
2. Introduction and problem statement
3. Constraints and factors taken into account in the design process
4. Justifications for the aesthetics decisions
5. Economic breakdown
6. All alternative designs considered
7. Quality control testing
8. Rationale behind selecting the final design
9. Details on the prototype construction
10. Calculations of the estimated load capacity
11. Summary of the load testing
12. Post-mortem (or forensic) analysis on the prototype performance and points of failure
13. Lessons learned: suggestions on how the design can be refined
14. Conclusions and final recommendations to the mayor

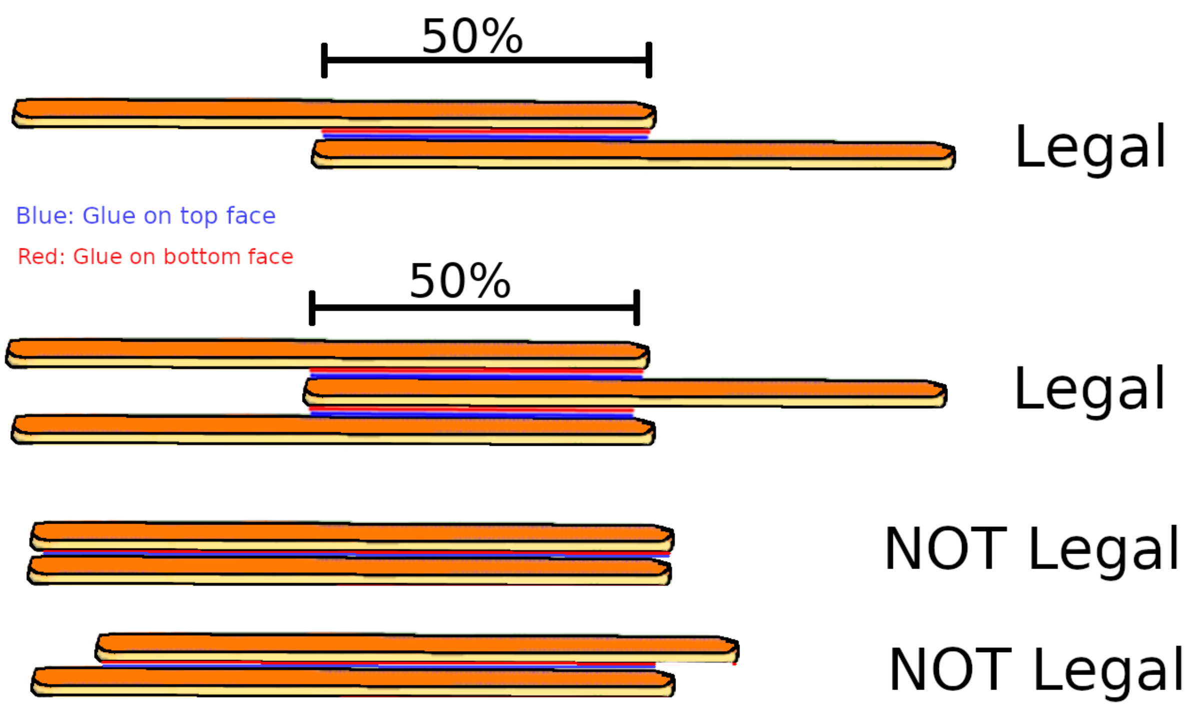
The report should include at least the following sections (you can change their order as you wish):

Note: all references used anywhere during the design process must be properly cited in the final report. Plagiarism of any kind will not be tolerated.

Important Design Constraints

- You must strictly adhere to the dimensional constraints presented above.
- Bridges constructed out of any materials other than the ones provided will result in an automatic disqualification.
- Bridges must be constructed prior to the prototype testing day; no same-day modifications will be allowed.

- No more than 50% of a plane side of a stick may be glued to other sticks (i.e. 50% of each side of all sticks must remain unglued). See figures below.
    - Any violation of this rule will result in an automatic disqualification.
- Craft sticks may not be altered or modified in any way, with the exception of cutting and sanding.
    - Sticks may not be cut to form notches, hinges, or any other inter-connecting parts.
- Bridges must have a clear opening along its center to allow for the insertion of the testing rod.
- The bridge must not be painted or coated with any material (including glue). You are only allowed to write down your company's name using a regular blue ink pen.
- Glue may only be used at the joints/connection between different sticks.
- I-beams are not allowed anywhere in the bridge
- T-beams are only allowed to be elements of the roadway.



Some Recommendations

- White glue needs at least 24 hours to dry, and it will get stronger if allowed to dry for 2 days or more. Design and build the bridge in advance. This will not only allow you to rectify things should you face unexpected problems, but will also ensure that your final prototype is stronger.
- Try using big paper clips to clamp the sticks together while the glue dries; it will make for a stronger bond.
- The West Point Bridge Designer is a great tool. Try using it for analyzing your design ideas.
- Research around for bridge-related references that could guide your design.
    - Recall: plagiarism is not tolerated, and all references must be properly cited
- Remember your Statics class: the strongest/most stable structural shape is the triangle.
- Notice how a popsicle stick is much stiffer and stronger when on its edge. Think if you can somehow make use of this property.
- Symmetry in bridge construction is usually important to minimize twisting upon loading.
- Test the bridge before the final day. Put it between two surfaces that are 60cm apart and press lightly on it. Check if it is stable 'enough' for the final loading test.

- Realize that the score is heavily influenced by the initial weight of the bridge. Try to maximize the strength of the bridge while keeping the weight as low as possible.
- Motivation: Our current ‘high-score’ stands at 35kg load on a 171g bridge (ER = 200). Do you have what it takes to be the next top scorer?

The town of Elmirsville appreciates your effort and contribution

The Mayor